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A mother whose paycheck solely supports her family of five. A homeless man reporting to his very first job. A newly released prisoner ready for a chance to rebuild. Recycling for a Change wants to change their lives—and the future of waste management in Brazil.

Waste picker cooperatives are responsible for sorting trash and selling it to recycling companies. All profits from those sales are equally divided among cooperative workers. As cooperatives succeed or fail, so do workers, families, and communities.

Funded by Dow, Recycling for a Change brings improved training, equipment, administration, and professionalism to cooperatives and workers.

The five cooperatives selected to test the program employ 214 workers but touch at least 450 more dependent family members. As cooperatives professionalize, workers experience a new sense of dignity and pride in the role they play within the larger waste management chain. Armed with this new mind-set, they view their job as a career with real social value.

"I don't really see myself as a waste picker. I see myself as an environmental agent."

TELINES BASILIO, PRESIDENT OF COOPERCAPS COOPERATIVE

Dow's support enables two key partners to activate the program. The start-up Boomera focuses on improving infrastructure, process, and waste management training. Before introducing any changes or optimizations, operations are carefully evaluated. Instead of one-size-fits-all solutions, new equipment and processes are designed to overcome each location's specific problems. Results are then measured and honed to maximize progress.

The nongovernmental organization (NGO) Fundación Avina is responsible for developing people, improving administration, and managing projects and budgets. Its inclusive recycling approach emphasizes waste management's human element and social impact. Dow is sharing its expertise in health and sanitation to improve working conditions and safety.

The initiative also creates a better-quality supply for production of postconsumer resin. This provides a new, bigger sales stream for cooperatives and connects to a circular economy model in which plastic waste is recycled and reused, over and over, never reaching the environment.

Leaders note that workers themselves are the true key to success. How do they feel about the new gains? "For the first time I see waste as something of real value." "I'm making my city and my family more sustainable."

"I've felt so many improvements within ourselves, our relationships, and the way we're organized."

THAIS RODRIGUES, MANAGER, COOPERATIVE CRESCER

Within months of its inception, productivity climbed to 70 percent sales increased by up to 50 percent, and average monthly salaries rose above minimum wage. While leaders agree that the initial results are remarkable, potential for much more lies ahead. As new equipment and processes are fully implemented, production could double. Ultimately, the program aims to perfect the prototype and create an open-source model that can be replicated at other cooperatives in Brazil and across Latin America. They call São Paulo just the first "nudge" that will unlock the full potential of workers, cooperatives, and communities.

CHANGE HAS A NAME

Noemia, Joselino, and Bárbara. The initiative is bringing this family, and so many others, together to lead change. Training effective leaders is critical to success now, and to continued growth after the initiative ends. New leadership skills are translating to stronger relationships with government, larger contracts, elevated roles for women, deeper bonds of trust with workers, and the ability to lead by hands-on example rather than by command.

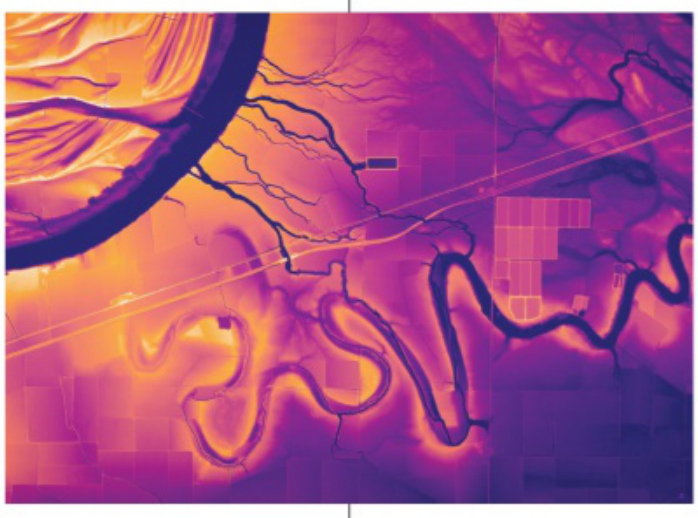


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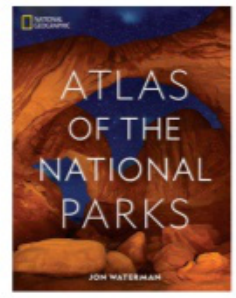
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A YEAR-END REFLECTION

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NATIONAL GEOGRAPHIC helps people understand our world. Guided by that purpose, we tell stories across all content platforms where people seek them.

We're building on the work of the 131-year-old National Geographic Society, which gives innovative grants to amazingly talented individuals worldwide. We're embracing opportunities to increase our impact like never before, thanks to our new partnership with The Walt Disney Company. Through our involvement in platforms like the new Disney+ streaming service, and taking advantage of Disney's unrivaled success in touching millions through parks, experiences, books, and other products, we will expand our reach across the globe. We're incredibly excited about all the possibilities that lie ahead for this new partnership.

This year we took our storytelling to new heights with award-winning journalism. We highlighted important concerns—the scourge of plastics in our ocean, the dangers of wildlife tourism, the global impact of climate change—and published a remarkable photography collection to celebrate how women are changing the world. The magazine's work was a finalist for a Pulitzer Prize (for the second time in three years), and our print and digital journalism won the National Magazine Awards' most prestigious honor, General Excellence.

Television viewers thrilled to the Academy Award-winning film *Free Solo,* relived an Ebola virus crisis via *The Hot Zone,* and "tasted" the world with chef Gordon Ramsay through his exclusive original series *Uncharted*. We built on our success in documentary filmmaking with important releases: *Sea of Shadows,* a riveting account of the desperate effort to save Earth's most endangered marine mammal from extinction; and *The Cave,* the heroic story of one female doctor working to save lives in war-torn Syria.



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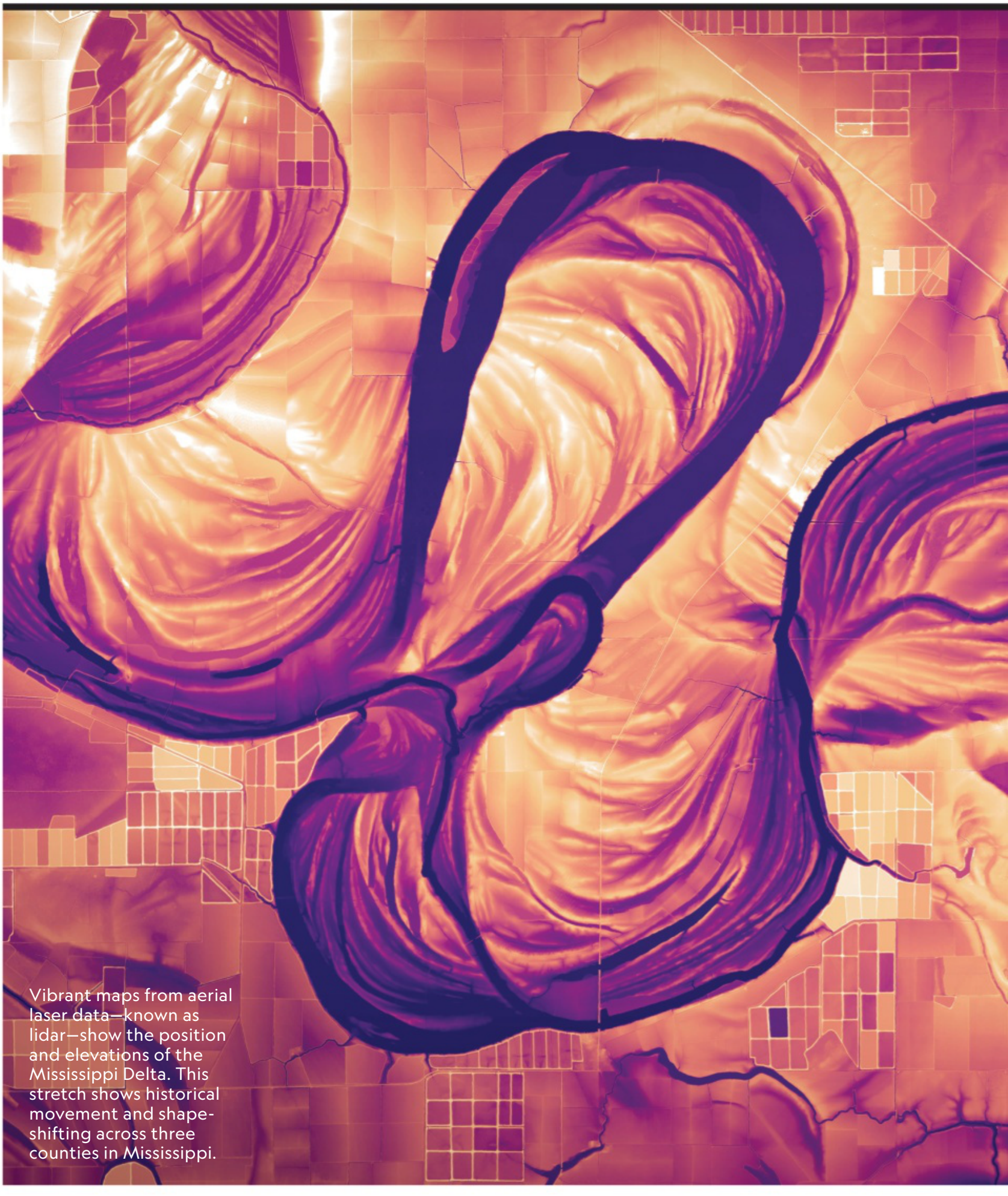
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PROOF

NATIONAL GEOGRAPHIC

IMAGES BY **DANIEL COE**

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE



Vibrant maps from aerial laser data—known as lidar—show the position and elevations of the Mississippi Delta. This stretch shows historical movement and shape-shifting across three counties in Mississippi.

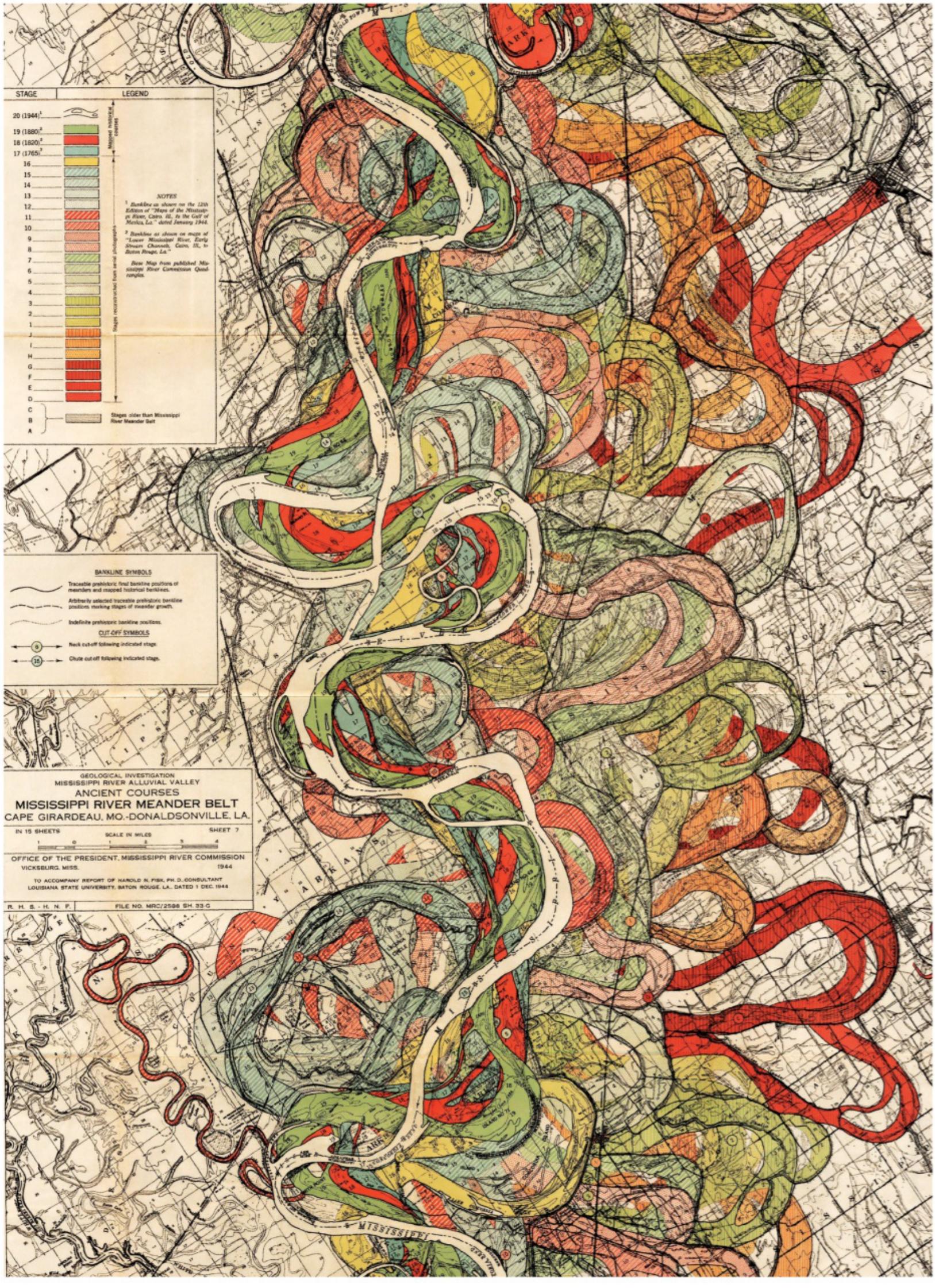
THE MEANDERING MISSISSIPPI

An innovative cartographer gives the Mississippi River—and its history—a high-tech new look.

VOL. 236 NO. 6



PROOF



A 1944 map by geologist Harold Fisk charts a 40-mile stretch of the Mississippi River from Friars Point to Gunnison, Mississippi. Fisk used aerial photos and maps to estimate the past and then-present channels.



By comparison, a map created using lidar shows shifts over the past 75 years. Erosion and changes in flow caused the channel to widen in the middle of the image and migrate toward the south.

PROOF



Mississippi's Tunica Lake, in this image's central oxbow bend, was once part of the Mississippi River. In the 1940s the Army Corps of Engineers cut the bend to straighten the river and shorten the shipping route.







Rivers meander by eroding one bank and depositing sediment on the other. The colors show the elevation differential of the current river and surrounding land: Blue is the lowest, white is the highest.

THE BACKSTORY

A CREATIVE MAPMAKER SHOWS THE MISSISSIPPI RIVER'S HISTORICAL TWISTS AND TURNS.

FOR CARTOGRAPHERS and cartophiles, Harold Fisk's 1944 maps of the lower Mississippi River are a seminal work. In the mid-20th century the geologist charted the river in stunning detail and accuracy, using aerial photos and local maps. The centerpiece of his report was 15 maps showing the meandering Mississippi and its historical floodplains stretching from Missouri to southern Louisiana.

More than seven decades later, Daniel Coe, a cartographer for the Washington Geological Survey, wanted to re-create Fisk's maps with greater accuracy and a new aesthetic. Coe had the advantage of hyperprecise U.S. Geological Survey (USGS) data collected using lidar, a system of laser pulses sent from aircraft to measure topography. The lasers detect the river's shape along with everything around it—every house, tree, and road. Strip away these layers of vegetation and human add-ons, and Coe's maps show the river's bare-ground geomorphology: once lazy bends replaced by direct flow, old floodplains cut off by levees and dikes.

USGS scientists collect lidar data (almost all of it open-source) to visualize how land evolves, and enterprising mapmakers can interpret the data in new ways. Slight changes in elevation can be the difference between a peaceful river and a devastating flood. Excessive soil runoff from agriculture can cause river migration and create longer shipping routes.

All of the above makes a river's past behavior the best indicator of how it might react to future landslides, floods, or erosion. "The most surprising thing is how much of an imprint is still left on the landscape," says Coe. "It's like seeing fingerprints the river left behind." —DANIEL STONE



Lidar reveals Louisiana's Wax Lake delta. Colors show elevation from dark (low) to light (high).

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A New Look in Circuses
Anatomy of an Orchid

THE DISCOVERIES OF TODAY THAT WILL DEFINE THE WORLD OF TOMORROW

NATIONAL GEOGRAPHIC | VOL. 236 NO. 6

The Lure of Cold Places

LEAVE THE TROPICS AND THE DESERTS TO OTHERS. A CERTAIN HARDY BREED PREFERS POLAR LOCALES, THE COLDER THE BETTER.

BY **KIERAN MULVANEY**

ON THIS WINTRY DAY along the shores of Canada's Hudson Bay, five of us are rumbling over the tundra in a purpose-built vehicle, searching for polar bears. Outside, a snowstorm has created near-whiteout conditions; it is, observes one of our number, as if we are driving inside a Ping-Pong ball.

Then the heat goes out in our Tundra Buggy, and despite repeated attempts at resuscitation, it refuses to sputter back to life. There is nothing but a thin layer of glass and metal protecting us from the elements.

The sun is setting. It is cold.

But we are perfectly safe; we're within range of warm accommodations, even if we'll be feeling the effects of the elements by the time we get there. We bury ourselves deep within our insulated parkas. We find a bottle of wine, and one of whiskey. We crack slightly hysterical jokes about our situation.

It is cold, but we are happy, and I am in my element.

ONE OF THE GREAT JOYS OF BEING IN THE COLD IS KEEPING IT AT BAY. PUSHING THROUGH WINTER, TO EMERGE ON THE OTHER SIDE, ELICITS A FEELING OF COMMUNAL TRIUMPH.

From crunching through Arctic sea ice on icebreakers to battling through Antarctic storms, from living in a cabin in Alaska to standing at the North Pole, most of my life highlights involve bracing against occasionally mind-numbing chill. These are the places and environments in which I feel most at home, the places where I choose to live and the ones I long to visit, the environments to which I always return.

Which is not to say I embrace the cold without reservation. There are nights when I kick through the snow like a happy child, overjoyed at how beautiful winter can be. There are also days when I frantically train space heaters on frozen pipes and wish I lived in, say, Hawaii. I'll not deny that there are times when my favorite part of winter is the fact that spring will soon replace it. I'm not alone in this, even among chionophiles (the scientific name for us cold fans). "I love the quietness" of life in cold climates, says my friend Alysa McCall—a scientist with Polar Bears International, a resident of Yellowknife, Canada (where winter temperatures can reach the minus 40s), and a fellow passenger in the aforementioned freezing Tundra Buggy. But, she confesses, "I have definitely been outside waiting for the bus in the middle of winter and wishing that the air didn't hurt."

Another friend takes it further. Eric Larsen has skied to the North and South Poles, ascended Everest, and traversed the Greenland ice sheet. The tagline in his emails is "It's Cool to Be Cold!" And yet, he notes with a laugh, "I don't like to be cold, quite honestly. I hate being cold. I like being warm in cold places."

I hadn't thought of that until Eric mentioned it, but he's right. It may sound counterintuitive, but one of the great joys of being in the cold is keeping it at bay. Meeting that challenge engenders a special camaraderie: the reliance and partnership that teams feel when setting out on a polar quest; the knowing nod between strangers, bundled up to the eyeballs, passing each other in the frozen streets. Pushing through winter, to emerge on the other side, elicits a feeling of communal triumph.

In a world that seems to move ever faster, where smartphones and social media demand immediate responses, the cold enforces a slowing down. It allows us—even compels us—to be aware of self and surroundings in a way that few other environments can.

Life at low temperatures requires more thoughtfulness because of the "lack of safety that being in

Explorers praised, reviled the cold

The cold regions of the globe can torment as much as they can transfix, as some renowned explorers have made clear.

"The land looks like a fairy tale," observed Roald Amundsen on his way to beating Robert Falcon Scott to the South Pole in 1911. Understandably, Scott saw it differently. "Great God! This is an awful place," he raged into his diary after realizing that Amundsen had bested him.

Jean-Baptiste Charcot had a love-hate relationship with Antarctica, which he explored in the early 1900s. "Why then do we feel this strange attraction for these polar regions, a feeling so powerful and lasting that when we return home we forget the mental and physical hardships and want nothing more than to return to them?" the French oceanographer mused. "Why are we so susceptible to the charm of these landscapes when they are so empty and terrifying?" –KM



CMANNPHOTO, GETTY IMAGES

cold environments presents," Eric says. He perceives "a level of severity in these cold environments that I find really attractive because it's a bigger challenge."

IT'S ALSO A CHALLENGE that fewer and fewer of us may ultimately have the opportunity to accept. While there's no danger of cold places vanishing from the planet in the foreseeable future, their extent, and the length and depth of their coldest periods, may be shrinking. The world is warming. And the cold is warming most of all.

Since the turn of the 20th century, average winter temperature in the United States has increased by almost twice the rate of the summer temperature. Over the past five to six decades, the Arctic has warmed by approximately four degrees, substantially more than the rest of the globe; annual minimum Arctic sea ice extent is declining by about 13 percent per decade. As I write this in the northern summer of 2019, Greenland's ice sheet is experiencing rates of melt that models had not predicted until 2070.

Here I should correct what I wrote earlier about standing *at* the North Pole: To be precise, I stood in close proximity to it. When I was there in August 2017, the area around the pole itself was mostly open water.

I think of Eric saying how different his last North Pole trip was from others—how he kept falling through ice thinner and more broken than he'd ever experienced. I think of another friend, who spent decades studying seals on Arctic sea ice, lamenting that his son wouldn't have a chance to do the same.

I think anew of my own experiences in the cold, and how impoverished my life would have been without them. I think of Antarctica's Ross Sea in January 1993, of climbing up a cliffside with a fellow crew member of the M.V. *Greenpeace* and sitting at the top, looking down at the bay below. Ours had been a long and arduous expedition, scouring the ocean for whaling ships that did not want to be found. For several days previously, Antarctica had thrown its worst at us, bombarding our ship with screaming gales and freezing waves until the vessel was coated with a thick layer of ice. When the storm abated and after the ice had been chipped away, my crewmate and I took the opportunity to set foot ashore.

The fierce wind bit angrily at the small patches of exposed skin on our faces, and we retreated into the scarves and hoods that cloaked our heads. And then, suddenly, the wind died down. For a moment there was silence. We looked at each other and grinned.

We didn't say a word. We didn't need to. We just sat there, on a cliff top in Antarctica. Smiling. In the silence.

In the cold. ▯

Kieran Mulvaney is a wildlife and environment writer whose books include *At the Ends of the Earth: A History of the Polar Regions*. When not voyaging in the Arctic and Antarctic—his ninth trip was this year—Mulvaney lives in the relative warmth of Vermont.



Canadian ice fishing shelters, from the series *Ice Huts* by Richard Johnson

PHOTOS: RICHARD JOHNSON GALLERY (ALL ABOVE)





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XOFLUZA™ (zoh-FLEW-zuh) (baloxavir marboxil) tablets

What is XOFLUZA?
XOFLUZA is a prescription medicine used to treat the flu (influenza) in people 12 years of age and older who have had flu symptoms for no more than 48 hours. It is not known if XOFLUZA is safe and effective in children less than 12 years of age or weighing less than 88 pounds (40 kg).

Do not take XOFLUZA if you are allergic to baloxavir marboxil or any of the ingredients in XOFLUZA.

Before you take XOFLUZA, tell your healthcare provider about all of your medical conditions, including if you:
- are pregnant or plan to become pregnant. It is not known if XOFLUZA can harm your unborn baby.
- are breastfeeding or plan to breastfeed. It is not known if XOFLUZA passes into your breast milk.

Tell your healthcare provider about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Talk to your healthcare provider before you receive a live flu vaccine after taking XOFLUZA.

How should I take XOFLUZA?
- Take XOFLUZA exactly as your healthcare provider tells you to.
- Your healthcare provider will prescribe 2 tablets of XOFLUZA you will take at the same time as a single dose.
- Take XOFLUZA with or without food.
- Do not take XOFLUZA with dairy products, calcium-fortified beverages, laxatives, antacids or oral supplements containing iron, zinc, selenium, calcium or magnesium.

If you take too much XOFLUZA, go to the nearest emergency room right away.

What are the possible side effects of XOFLUZA?
XOFLUZA may cause serious side effects, including:
Allergic reactions. Get emergency medical help right away if you develop any of these signs and symptoms of an allergic reaction:
- trouble breathing
- swelling of your face, throat or mouth
- skin rash, hives or blisters
- dizziness or lightheadedness

The most common side effects of XOFLUZA in adults and adolescents include:
- diarrhea
- bronchitis
- sinusitis
- headache
- nausea

XOFLUZA is not effective in treating infections other than influenza. Other kinds of infections can appear like flu or occur along with flu and may need different kinds of treatment. Tell your healthcare provider if you feel worse or develop new symptoms during or after treatment with XOFLUZA or if your flu symptoms do not start to get better.

These are not all the possible side effects of XOFLUZA.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.
Keep XOFLUZA and all medicines out of the reach of children.

General information about the safe and effective use of XOFLUZA.

Medicines are sometimes prescribed for purposes other than those listed in a Patient Information leaflet. Do not use XOFLUZA for a condition for which it was not prescribed. Do not give XOFLUZA to other people, even if they have the same symptoms that you have. It may harm them. You can ask for information about XOFLUZA that is written for health professionals.

You are encouraged to report side effects to Genentech by calling 1-888-835-2555 or to the FDA by visiting www.fda.gov/medwatch or calling 1-800-FDA-1088.

For more information, go to www.xofluza.com

Eligible patients may
PAY AS LITTLE AS $30
for their XOFLUZA prescription, up to $60 off.†

Visit XOFLUZA.com/save or text **COUPON** to 96260 to get a coupon.

†Terms and conditions apply. Message and data rates apply.

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GENIUS

LILLYGOL SEDAGHAT

BY **ANNIE ROTH** PHOTOGRAPH BY **REBECCA HALE**



She puts a new spin on 'waste not, want not' by treating trash as a valuable resource.

Banana peels and plastic straws are little more than garbage in most of the world. To environmental educator Lillygol Sedaghat, they're precious commodities. For the past two years, the 27-year-old National Geographic explorer has traveled the globe to advocate for the untapped potential of trash. The linear economy, where resources are turned into disposable products, "is no longer sustainable," Sedaghat says. She aims to promote a circular economy, in which "you maximize your resources and minimize your waste." Since 2017 Sedaghat has researched one of the world's most efficient waste management systems: Taiwan recycles nearly half its municipal waste and has reduced the amount sent to landfills to less than one percent—turning plastic waste into cell phone cases and food scraps into fertilizer. To Sedaghat, it's a prime example of how a zero-waste economy can work. Her goal? For people "to realize a) they are a part of a waste system, b) they could make a difference and live a more sustainable lifestyle, [and] c) that our trash doesn't disappear, it goes somewhere and affects someone." ▯

Learn more about plastic waste and take the pledge to reduce it at *natgeo.com/plasticpledge*.

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You can leave the world better than you found it. When you leave a gift to the National Geographic Society in your will, trust, or by beneficiary designation, you can protect critical animal species for generations to come. There is no minimum amount and **your gift costs you nothing now**. It's an easy way to make a lasting difference.

NATIONAL GEOGRAPHIC



PHOTO: JOEL SARTORE
NATIONAL GEOGRAPHIC PHOTO ARK

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DISPATCHES
FROM THE FRONT LINES
OF SCIENCE
AND INNOVATION



If ticks bite, opossums bite back

Black-legged ticks, which spread Lyme disease in much of North America, feed on various hosts. One, the opossum, is a tick-eliminating champ, grooming away 96 percent of tick larvae that infest it, a research study says. Preserving Earth's biodiversity helps keep this and other natural pest traps on the job, the study concludes. –PATRICIA EDMONDS

ANTHROPOLOGY

Worked to the bone in antiquity

In millennia-old bones, scientists can see how the sexes divided chores. A U.K. study of prehistoric agriculturalists' remains found signs in men's arm and leg bones that they did hard labor. But women's arm bones also showed signs of manual labor and impressive strength—up to 40 percent greater than a control group of modern women. Anthropologist Alison Macintosh Murray says the findings refute the idea that women didn't do "as much as the men." –PE





ANIMAL WELFARE

GLOWING NEW ACTS TO SEE UNDER THE BIG TOP

CIRCUS NOSTALGIA MEETS MODERN TECHNOLOGY

At Circus Roncalli, based in Cologne, Germany, the dancing elephant is 20 feet tall. Such a behemoth should weigh more than 10 tons, but this creature is weightless—and slightly translucent. It's a three-dimensional hologram, a six-million-pixel creation that performs thanks to 15 engineers, more than 3,000 processors, and 11 laser beams. The spectacle is "a combination of nostalgic circus with modern elements," says founder and director Bernhard Paul, who invested in the technology after watching a hologram of the late rock star Prince perform at the 2018 Super Bowl. The circus animates holographic fish and horses as well as elephants but bills itself as "otherwise animal free." The innovation has been applauded for respecting both circus tradition and animal protection. –CLAIRE WOLTERS

PHOTOS (FROM TOP): JOEL SARTORE, NATIONAL GEOGRAPHIC PHOTO ARK; CIRCUSTHEATERRONCALLI; DIDIER DESCOUENS, MUSÉUM DE TOULOUSE


Birdwatching, Caño Negro


Toucan

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Day 3 Wildlife Rescue, Fortuna
Visit a wildlife rescue center where injured animals are rehabilitated for release back into the wild. Then, to Fortuna in the San Carlos Valley for a two night stay.

Day 4 Rio Frio Cruise, Hot Springs
Cruise on the Rio Frio, gateway to the Caño Negro wildlife refuge. Watch for water-walking lizards, caimans, and howler monkeys. Soak in the volcanic hot springs.

Day 5 Hanging Bridges, Beach
Hike on the Hanging Bridges, view majestic Arenal Volcano, and take a scenic drive around Lake Arenal. Continue to the Pacific Coast for a relaxing two night stay.

Day 6 Turtle Park, Beach
Visit Leatherback Turtle National Park. These marine reptiles are the largest in the world, weighing over 1,500 pounds. Free time at the J.W. Marriott Resort and Spa.

Day 7 Cruise, Manuel Antonio
Cruise on the Tarcoles River. Enjoy bird watching and crocodile spotting. Stay in Manuel Antonio directly next to the park entrance.

Day 8 Manuel Antonio
Visit Manuel Antonio National Park, a natural habitat for the three-toed sloth and the rare squirrel monkey. Look for toucans and parrots. Hike the rainforest and beach coves. Enjoy a farewell dinner tonight.

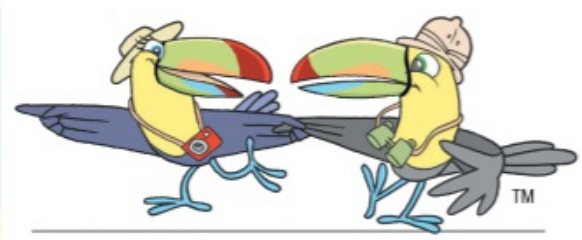
Day 9 San José
Tour ends after breakfast. Caravan provides Airport transfers. Thanks for vacationing with Caravan!

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3, 4	**Fortuna** Magic Mountain
5, 6	**Guanacaste** J.W. Marriott
7	**Manuel Antonio** San Bada
8	**San José** Real InterContinental

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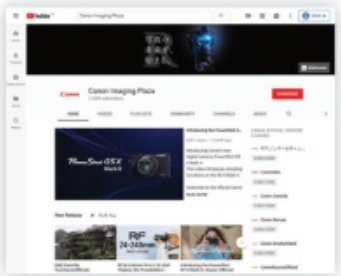
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SUBARU



IN ORCHIDS, MYT
FOLK MEDICINE M

PHOTOGRAPH BY **ANDRÉS M.**

THE WORD OF THE DAY: ORCHIS. It's a genu
plant. It's the Greek word for testicle (whi
tubers ostensibly resemble). And in Gree
Orchis was a brute whose punishment for
priestess was to be torn into pieces—from
a plant with testicle-like tubers. Since an
orchids have been "associated with sexu
Journal of Cultural Heritage. In some soc
still consume the plant, hoping that thei
will benefit. Orchid tubers are eaten as i
fighters in Israel; bulbs, as aphrodisiacs i
the flowers are consumed in Italy, where s
the anatomically explicit *Orchis italica* (pi
aka the naked man orchid. –PATRICIA EDM



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DOMÍNGUEZ

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EXPLORE

IN THIS SECTION
Bridge of Roots
Sylvia Earle's Fins
Bedtime for Bears
—or Maybe Not

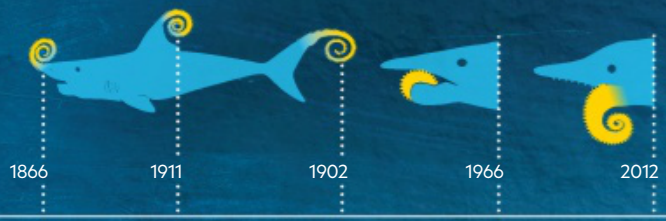
ILLUMINATING THE MYSTERIES—A VONDERS—ALL AROUND US EVERY DAY
NATIONAL GEOGRAPHIC | VOL. 236 NO. 6

BUZZ SAW MYSTERY

The fossils resembled blades of circular saws. Frozen in time, some of the ancient impressions revealed up to 150 razor-sharp wedges in tightly wrapped spirals, or whorls. For more than a century, scientists questioned: What were they? Answer: The killer jaws of the *Helicoprion*, an evolutionary outlier from 275 million years ago.

GUESSING GAME

Was the whorl part of its snout? A defensive fin? Theories abounded. It wasn't until 2013, when a fossil found in 1950—with attached cartilage—was CT scanned and computer modeled, that the answer was clear.



THEIR ANCIENT SEAS

The Permian predator thrived near shorelines in waters where now there are countries. Over 150 fossils have been found—many in Idaho, unearthed in phosphorus mines once deep underwater.

JAGGED JAWS

The spiral-toothed giants tripled in size over the eight million years they roamed the seas. Their unique jaws—an anatomical feature never seen again—could slice soft prey like a sword and detach creatures from their hard shells.

Up to 15 teeth could be exposed at the same time.



Modern relative
Spotted ratfish
(Hydrolagus colliei)

Female
Length 38 in

Skull (cartilage)

Upper jaw (cartilage)

Angle of open jaw

60°

90°

Great white

Helicoprion

Lower jaw

Single root

Prey

Upper jaw

Opening for attack

The *Helicoprion*'s gaping jaw far exceeded the mouth angle of today's great white shark but had only a third of the bite force, closer to that of a modern crocodile's jaw.

Catch and no release

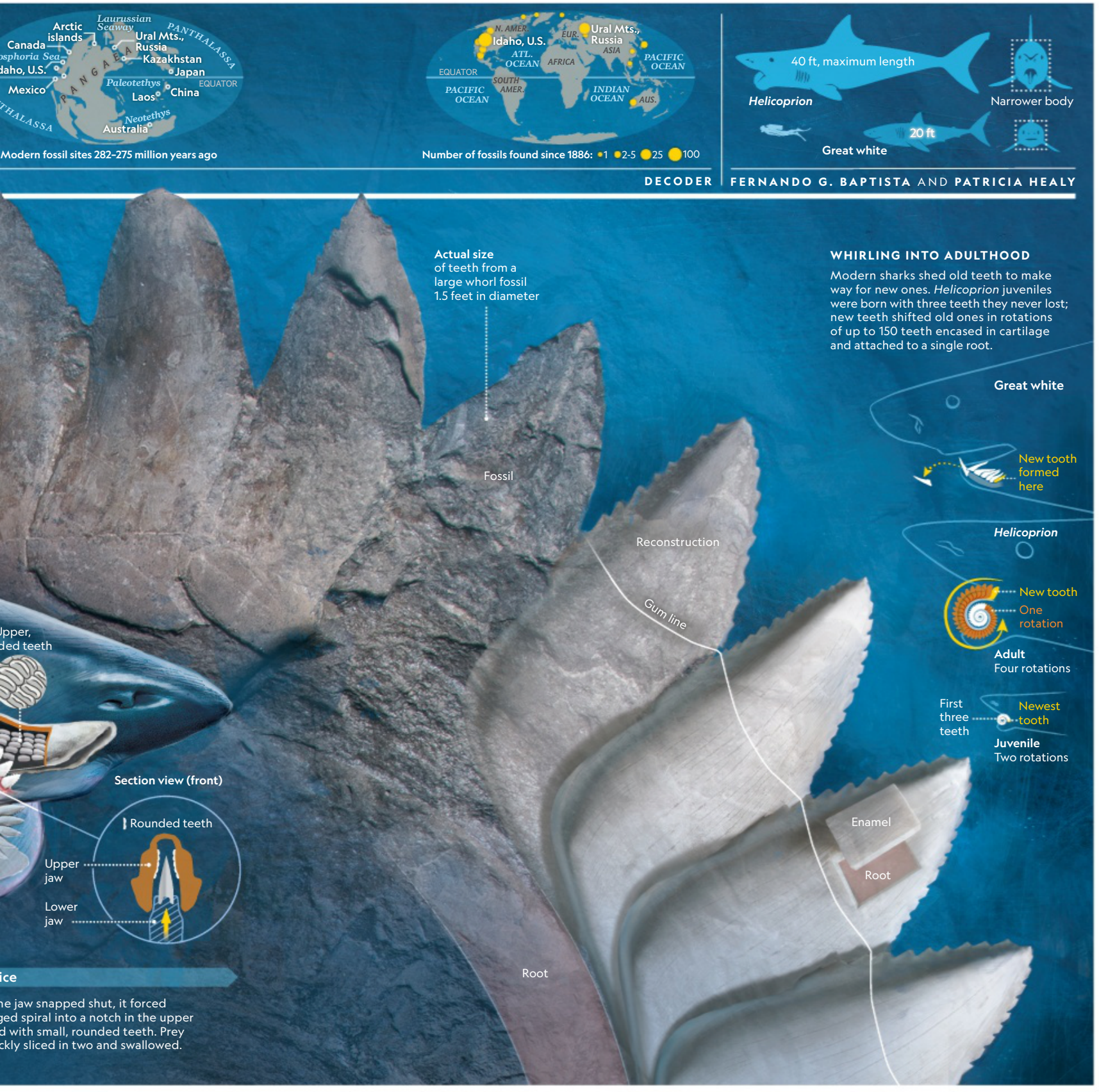
It gripped prey with middle teeth angled backward. As the jaw closed, back teeth pushed the kill deeper into the *Helicoprion*'s narrow mouth and throat.

Final sl

When th
the jagg
jaw line
was qui

DIANA MARQUES, JOHN KAPPLER, AND EVE CONANT, NGM STAFF

SOURCES: LEIF TAPANILA, IDAHO STATE UNIVERSITY; JESSE PRUITT, IDAHO MUSEUM OF NATURAL HISTORY; JOSHUA MOYER; GEORGE H. BURGESS, UNIVERSITY OF FLORIDA; C.R. SCOTESE (PERMIAN PALEOGEOGR



RAPHIC MAP)

PHOTO: EVELYN VOLLMER AT IDAHO VIRTUALIZATION LAB, IDAHO MUSEUM OF NATURAL HISTORY



"I WANTED IT TO LOOK LIKE THESE BRIDGES ARE SOMETHING RIGHT OUT OF *LORD OF THE RINGS*, AND THEN SAY, 'NO, THEY'RE NOT FICTION, THEY EXIST.'"
—Prasenjeet Yadav

IN THE INDIAN STATE of Meghalaya, one of the wettest places on Earth, villagers weave the roots of living rubber trees into sturdy pedestrian bridges. On a quest to document the tradition, Prasenjeet Yadav photographed around 30 root bridges over the course of a year.

A FEW MONTHS OUT
HOW TO GET THE SHOT

Yadav had never visited a living root bridge before embarking on this project, but he knew of this particular bridge near the village of Nohwet. With so many tourists shooting photographs, Yadav wanted his image to stand out. "It's difficult to make a plant look charismatic," he says. To prepare, he consulted other photographers and studied landscape paintings. He decided to take the shot after dark. It was risky: Unexpected cloudbursts can spawn flash floods, which can be especially dangerous at night.

TWO WEEKS OUT
ESSENTIAL PACKING LIST

As this was Yadav's fourth trip to the region, he knew what to pack. Paring supplies to the basics, he brought little rainwear for himself and prioritized keeping his camera dry.

- Umbrellas to cover the camera gear
- Granola bars
- Flashlights and an LED light panel
- A strong headlamp
- Rubber housing to protect the camera
- A tripod
- A sheet of black Cinefoil to shield the lens
- Light modifiers

LAUNCH
'PAINTING' WITH LIGHT

From his home base of Bangalore, Yadav flew to Guwahati and took a cab to Nohwet. From there, he walked 30 minutes to the bridge. During a three-week stay, Yadav experimented with using lights to "paint" parts of the bridge and surroundings during a long exposure. In the 438 seconds it took to expose this image, Yadav moved between locations to aim his lights. Shrouded in darkness, he's not visible in the final photograph.

A TANGLED RIVER

In northeastern India, heavy rains erode infrastructure. So villagers

CROSSING

make their own bridges—out of living trees.

BY **NINA STROCHLIC** PHOTOGRAPH BY **PRASENJEET YADAV**

BY THE NUMBERS

200 years

ESTIMATED AGE OF THIS BRIDGE

2,040 inches

STATE'S TOTAL RAINFALL IN 2016

6,460

APPROXIMATE NUMBER OF VILLAGES IN THE STATE



The state of Meghalaya is known as the "abode of the clouds."

NGM MAPS

KEYTRUDA immunotherapy + chemotherapy (pemetrexed and a platinum) for advanced nonsquamous, non–small cell lung cancer that does not have an abnormal EGFR or ALK gene.

"A year after my diagnosis, I couldn't be happier with my results. Where I am now compared to a year ago, it's a story worth sharing."

—Katy

KEYTRUDA will not work for everyone. Results may vary.

A clinical trial compared patients with advanced nonsquamous, non–small cell lung cancer (NSCLC) who received KEYTRUDA in combination with chemotherapy (410 patients) with those who received chemotherapy alone (206 patients). Patients in the trial did not have an abnormal EGFR or ALK gene and had no previous drug treatment.

WHEN TREATED WITH A COMBINATION OF KEYTRUDA AND CHEMOTHERAPY:

MORE PATIENTS LIVED LONGER

69% of patients taking KEYTRUDA with chemotherapy were alive compared with 48% taking chemotherapy alone.

MORE PATIENTS SAW THEIR TUMORS SHRINK

48% of patients taking KEYTRUDA with chemotherapy saw their tumors shrink compared with 19% taking chemotherapy alone.

The median duration of response to treatment was 11.2 months for patients treated with a combination of KEYTRUDA and chemotherapy compared with 7.8 months for those on chemotherapy alone.

KEYTRUDA is a prescription medicine used to treat a kind of lung cancer called NSCLC. KEYTRUDA may be used with the chemotherapy medicines pemetrexed and a platinum as your first treatment when your lung cancer has spread (advanced NSCLC) **and** is a type called "nonsquamous" **and** your tumor does not have an abnormal "EGFR" or "ALK" gene.
EGFR = epidermal growth factor receptor;
ALK = anaplastic lymphoma kinase.

IMPORTANT SAFETY INFORMATION

KEYTRUDA is a medicine that may treat certain cancers by working with your immune system. KEYTRUDA can cause your immune system to attack normal organs and tissues in any area of your body and can affect the way they work. These problems can sometimes become severe or life-threatening and can lead to death. These problems may happen any time during treatment or even after your treatment has ended.

Call or see your doctor right away if you develop any symptoms of the following problems or these symptoms get worse:

- **Lung problems (pneumonitis).** Symptoms of pneumonitis may include shortness of breath, chest pain, or new or worse cough.
- **Intestinal problems (colitis) that can lead to tears or holes in your intestine.** Signs and symptoms of colitis may include diarrhea or more bowel movements than usual; stools that are black, tarry, sticky, or have blood or mucus; or severe stomach-area (abdomen) pain or tenderness.
- **Liver problems, including hepatitis.** Signs and symptoms of liver problems may include yellowing of your skin or the whites of your eyes, nausea or vomiting, pain on the right side of your stomach area (abdomen), dark urine, or bleeding or bruising more easily than normal.
- **Hormone gland problems (especially the thyroid, pituitary, adrenal glands, and pancreas).** Signs and symptoms that your hormone glands are not working properly may include rapid heartbeat, weight loss or weight gain, increased sweating, feeling more hungry or thirsty, urinating more often than usual, hair loss, feeling cold, constipation, your voice gets deeper, muscle aches, dizziness or fainting, or headaches that will not go away or unusual headache.
- **Kidney problems, including nephritis and kidney failure.** Signs of kidney problems may include change in the amount or color of your urine.
- **Skin problems.** Signs of skin problems may include rash, itching, blisters, peeling or skin sores, or painful sores or ulcers in your mouth or in your nose, throat, or genital area.
- **Problems in other organs.** Signs and symptoms of these problems may include changes in eyesight; severe or persistent muscle or joint pains; severe muscle weakness; low red blood cells (anemia); swollen lymph nodes, rash or tender lumps on skin, cough, shortness of breath, vision changes, or eye pain (sarcoidosis); confusion, fever, muscle weakness, balance problems, nausea, vomiting, stiff neck, memory problems, or seizures (encephalitis); and shortness of breath, irregular heartbeat, feeling tired, or chest pain (myocarditis).
- **Infusion (IV) reactions that can sometimes be severe and life-threatening.** Signs and symptoms of infusion reactions may include chills or shaking, shortness of breath or wheezing, itching or rash, flushing, dizziness, fever, or feeling like passing out.

Important Safety Information is continued on the next page.

IT'S TRU.

KEYTRUDA® (pembrolizumab) Injection 100 mg

Learn more at keytruda.com



Half of the patients receiving KEYTRUDA with chemotherapy were alive without their cancer spreading, growing, or getting worse at 8.8 months compared with 4.9 months for patients receiving chemotherapy alone. Cancer did not progress in 40% of patients receiving KEYTRUDA with chemotherapy compared with 19% of patients receiving chemotherapy alone.

The immunotherapy with the most FDA-approved uses for advanced lung cancer

IMPORTANT SAFETY INFORMATION *(continued)*

- **Rejection of a transplanted organ.** People who have had an organ transplant may have an increased risk of organ transplant rejection if they are treated with KEYTRUDA.
- **Complications, including graft-versus-host disease (GVHD), in people who have received a bone marrow (stem cell) transplant that uses donor stem cells (allogeneic).** These complications can be severe and can lead to death. These complications may happen if you underwent transplantation either before or after being treated with KEYTRUDA. Your doctor will monitor you for the following signs and symptoms: skin rash, liver inflammation, abdominal pain, and diarrhea.

Getting medical treatment right away may help keep these problems from becoming more serious. Your doctor will check you for these problems during treatment with KEYTRUDA. Your doctor may treat you with corticosteroid or hormone replacement medicines. Your doctor may also need to delay or completely stop treatment with KEYTRUDA if you have severe side effects.

Before you receive KEYTRUDA, tell your doctor if you have immune system problems such as Crohn's disease, ulcerative colitis, or lupus; have had an organ transplant or plan to have or have had a bone marrow (stem cell) transplant that used donor stem cells (allogeneic); have lung or breathing problems; have liver problems; or have any other medical problems.

If you are pregnant or plan to become pregnant, tell your doctor. KEYTRUDA can harm your unborn baby. If you are able to become pregnant, your doctor will give you a pregnancy test before you start treatment. Use effective birth control during treatment and for at least 4 months after the final dose of KEYTRUDA. Tell your doctor right away if you think you may be pregnant or you become pregnant during treatment with KEYTRUDA.

If you are breastfeeding or plan to breastfeed, tell your doctor. It is not known if KEYTRUDA passes into your breast milk. Do not breastfeed during treatment with KEYTRUDA and for 4 months after your final dose of KEYTRUDA.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Common side effects of KEYTRUDA when given with certain chemotherapy medicines include feeling tired or weak; nausea; constipation; diarrhea; decreased appetite; rash; vomiting; cough; trouble breathing; fever; hair loss; inflammation of the nerves that may cause pain, weakness, and paralysis in the arms and legs; swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina; and mouth sores.

These are not all the possible side effects of KEYTRUDA. Tell your doctor if you have any side effect that bothers you or that does not go away. For more information, ask your doctor or pharmacist.

Please read the adjacent Important Information About KEYTRUDA and discuss it with your oncologist.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

Having trouble paying for your Merck medicine? Merck may be able to help. www.merckhelps.com

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US-LAM-00406 07/19

MERCK

Important Information About KEYTRUDA® (pembrolizumab) injection 100 mg.

Please speak with your healthcare professional regarding KEYTRUDA (pronounced key-true-duh). Only your healthcare professional knows the specifics of your condition and how KEYTRUDA may work with your overall treatment plan. If you have any questions about KEYTRUDA, speak with your healthcare professional. **℞ONLY**

What is the most important information I should know about KEYTRUDA?

KEYTRUDA is a medicine that may treat certain cancers by working with your immune system. KEYTRUDA can cause your immune system to attack normal organs and tissues in any area of your body and can affect the way they work. These problems can sometimes become severe or life-threatening and can lead to death. These problems may happen anytime during treatment or even after your treatment has ended.

Call or see your doctor right away if you develop any symptoms of the following problems or these symptoms get worse:

Lung problems (pneumonitis). Symptoms of pneumonitis may include:

- shortness of breath
- chest pain
- new or worse cough

Intestinal problems (colitis) that can lead to tears or holes in your intestine. Signs and symptoms of colitis may include:

- diarrhea or more bowel movements than usual
- severe stomach-area (abdomen) pain or tenderness
- stools that are black, tarry, sticky, or have blood or mucus

Liver problems, including hepatitis. Signs and symptoms of liver problems may include:

- yellowing of your skin or the whites of your eyes
- dark urine
- nausea or vomiting
- bleeding or bruising more easily than normal
- pain on the right side of your stomach area (abdomen)

Hormone gland problems (especially the thyroid, pituitary, adrenal glands, and pancreas). Signs and symptoms that your hormone glands are not working properly may include:

- rapid heart beat
- urinating more often than usual
- your voice gets deeper
- weight loss or weight gain
- hair loss
- muscle aches
- increased sweating
- feeling cold
- dizziness or fainting
- feeling more hungry or thirsty
- constipation
- headaches that will not go away or unusual headache

Kidney problems, including nephritis and kidney failure. Signs of kidney problems may include:

- change in the amount or color of your urine

Skin problems. Signs of skin problems may include:

- rash
- blisters, peeling or skin sores
- itching
- painful sores or ulcers in your mouth or in your nose, throat, or genital area

Problems in other organs. Signs and symptoms of these problems may include:

- changes in eyesight
- severe or persistent muscle or joint pains
- severe muscle weakness
- low red blood cells (anemia)
- swollen lymph nodes, rash or tender lumps on skin, cough, shortness of breath, vision changes, or eye pain (sarcoidosis)
- confusion, fever, muscle weakness, balance problems, nausea, vomiting, stiff neck, memory problems, or seizures (encephalitis)
- shortness of breath, irregular heartbeat, feeling tired, or chest pain (myocarditis)

Infusion (IV) reactions that can sometimes be severe and life-threatening. Signs and symptoms of infusion reactions may include:

- chills or shaking
- itching or rash
- dizziness
- feeling like passing out
- shortness of breath or wheezing
- flushing
- fever

Rejection of a transplanted organ. People who have had an organ transplant may have an increased risk of organ transplant rejection. Your doctor should tell you what signs and symptoms you should report and monitor you, depending on the type of organ transplant that you have had.

Complications, including graft-versus-host-disease (GVHD), in people who have received a bone marrow (stem cell) transplant that uses donor stem cells (allogeneic). These complications can be severe and can lead to death. These complications may happen if you underwent transplantation either before or after being treated with KEYTRUDA. Your doctor will monitor you for the following signs and symptoms: skin rash, liver inflammation, stomach-area (abdominal) pain, and diarrhea.

Getting medical treatment right away may help keep these problems from becoming more serious. Your doctor will check you for these problems during treatment with KEYTRUDA. Your doctor may treat you with corticosteroid or hormone replacement medicines. Your doctor may also need to delay or completely stop treatment with KEYTRUDA, if you have severe side effects.

What should I tell my doctor before receiving KEYTRUDA?
Before you receive KEYTRUDA, tell your doctor if you:

- have immune system problems such as Crohn's disease, ulcerative colitis, or lupus
- have received an organ transplant, such as a kidney or liver
- have received or plan to receive a stem cell transplant that uses donor stem cells (allogeneic)
- have lung or breathing problems
- have liver problems
- have any other medical problems
- are pregnant or plan to become pregnant
 - KEYTRUDA can harm your unborn baby.

Females who are able to become pregnant:

- Your doctor will give you a pregnancy test before you start treatment with KEYTRUDA.
- You should use an effective method of birth control during and for at least 4 months after the final dose of KEYTRUDA. Talk to your doctor about birth control methods that you can use during this time.
- Tell your doctor right away if you think you may be pregnant or if you become pregnant during treatment with KEYTRUDA.

- are breastfeeding or plan to breastfeed.
 - It is not known if KEYTRUDA passes into your breast milk.
 - Do not breastfeed during treatment with KEYTRUDA and for 4 months after your final dose of KEYTRUDA.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Know the medicines you take. Keep a list of them to show your doctor and pharmacist when you get a new medicine.

How will I receive KEYTRUDA?

- Your doctor will give you KEYTRUDA into your vein through an intravenous (IV) line over 30 minutes.
- KEYTRUDA is usually given every 3 weeks.
- Your doctor will decide how many treatments you need.
- Your doctor will do blood tests to check you for side effects.
- If you miss any appointments, call your doctor as soon as possible to reschedule your appointment.

What are the possible side effects of KEYTRUDA?

KEYTRUDA can cause serious side effects. See "What is the most important information I should know about KEYTRUDA?"

Common side effects of KEYTRUDA when used alone include: feeling tired, pain, including pain in muscles, bones or joints and stomach-area (abdominal) pain, decreased appetite, itching, diarrhea, nausea, rash, fever, cough, shortness of breath, and constipation.

Common side effects of KEYTRUDA when given with certain chemotherapy medicines include: feeling tired or weak, nausea, constipation, diarrhea, decreased appetite, rash, vomiting, cough, trouble breathing, fever, hair loss, inflammation of the nerves that may cause pain, weakness, and paralysis in the arms and legs, swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina, and mouth sores.

Common side effects of KEYTRUDA when given with axitinib include: diarrhea, feeling tired or weak, high blood pressure, liver problems, low levels of thyroid hormone, decreased appetite, blisters or rash on the palms of your hands and soles of your feet, nausea, mouth sores or swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina, hoarseness, rash, cough, and constipation.

In children, feeling tired, vomiting and stomach-area (abdominal) pain, and increased levels of liver enzymes and decreased levels of salt (sodium) in the blood are more common than in adults.

These are not all the possible side effects of KEYTRUDA. For more information, ask your doctor or pharmacist.

Tell your doctor if you have any side effect that bothers you or that does not go away.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

General information about the safe and effective use of KEYTRUDA
Medicines are sometimes prescribed for purposes other than those listed in a Medication Guide. If you would like more information about KEYTRUDA, talk with your doctor. You can ask your doctor or nurse for information about KEYTRUDA that is written for healthcare professionals.

For more information, go to www.keytruda.com.

Based on Medication Guide usmg-mk3475-iv-1906r025 as revised June 2019.

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MERCK

FINS THAT HAVE A PLACE IN HISTORY

ITEMS IN THE NATIONAL GEOGRAPHIC ARCHIVES INCLUDE FAMOUS FOOTWEAR. THESE BELONGED TO SYLVIA EARLE.

PHOTOGRAPH BY **REBECCA HALE**

THEY'RE HUMBLE plastic-and-rubber dive fins, aged by hundreds of hours of exposure to salt water and sun—but they've been on great adventures. That's because their owner is the barrier-breaking, record-setting oceanographer Sylvia Earle.

As a student of marine science in the 1950s, Earle adopted scuba equipment early on. She was the first woman to enter a lockout chamber of an underwater submersible (and was four months pregnant at the time); she led the first all-woman aquanaut team to live underwater for two weeks. In 1979 she descended 1,250 feet in a pressurized suit to walk on the ocean floor off Oahu, setting a record for the deepest dive made without a tether. On land Earle, a National Geographic explorer-in-residence, was the first woman to be chief scientist of the U.S. National Oceanic and Atmospheric Administration.

How many pairs of fins has Earle gone through in her decades of scientific research? No one has an exact count. Nowadays she prefers a more high-tech fin design, a type also favored by U.S. special forces. The military's fins are black, though, while Earle's are a luscious red. She calls them her "ruby flippers." —NINA STROCHLIC



Earle used these fins during some of the roughly 8,000 hours she's spent underwater.



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Don't Wake the Bear



IN A REMOTE UTAH CAVE, A HIBERNATING BLACK BEAR GREETS UNEXPECTED VISITORS.

BY **COREY ARNOLD**

OUR TASK WAS simply to change some batteries.

But the batteries were in a radio collar worn by a male black bear in Bryce Canyon National Park, Utah. Wes Larson, a wildlife biologist at Brigham Young University who was figuring out how to reduce human-bear conflicts near backcountry campsites, had invited me along for a "little adventure": We would tranquilize the bear while he was hibernating.

On a cold and clear day in February, Wes, his brother Jeff, his assistant Jordan, and I were following the GPS coordinates from the bear's collar up a steep and into a red earth canyon covered in high desert brush and freshly fallen snow. The signal led us up the face of a steep hillside. The temperature dropped into the single digits as we poked at the snow, trying to locate the den's entrance.

A weak radio signal led us to several empty dens, and as the sun set, we considered turning back. Then a curtain of snow collapsed, revealing a sandstone cave. It narrowed to a dark tunnel, and the musky scent of wild animal steamed from within.

The tunnel was barely wide enough for a person to turn around in, and it kinked to the left, obscuring our view of what lay inside. Wes didn't hesitate. Armed with an expandable six-foot stick tipped with a tranquilizer syringe, he dived in headfirst. His brother crawled after him.

Thirty seconds later, they came flying backward out of the tunnel. The bear they'd collared a year and a half ago now weighed about 350 pounds—and he was awake. Wes had managed to jab him with the syringe, so we waited for the drug to take effect. When black bears hibernate, their breath slows and their body temperature drops by roughly 12 degrees



Fahrenheit—low enough to cut their metabolic rate in half, but high enough for them to react to danger. Then, crawling on forearms and knees, I followed Wes, feeling only slightly more secure knowing that he'd be chomped before me if the bear charged.

When we rounded the tunnel bend, wide eyes flashed at us. He was still awake. I quickly snapped the photo above. Wes told me to stay put while he backed out and prepared another dose of tranquilizer; if the bear escaped half sedated, he could fall into the canyon below.

The bear started crawling toward us until I was forced out of the den. We frantically blocked the exit with backpacks and sticks as Wes jabbed him again—but he powered through our barricade with groggy steps and began to crawl down the snowy slope. Jeff and Jordan lunged for his back paws, straining to hold on to him; Wes jumped on his back and grabbed his collar.

The bear pulled them down the hillside and came to rest in the lower branches of a pine tree. The tranquilizer had kicked in—he was asleep. Wes and his brother changed out the radio collar and checked his health, but we had one more daunting task: getting a limp 350-pound bear up the snowy embankment and safely back to his den before he awoke. We pushed and pulled with every muscle. Before the sedative wore off, we succeeded.

When spring came, signals from the bear's new radio collar showed he'd resumed his everyday life—avoiding any more contact, we hope, with humans. ▯

Corey Arnold is a photographer, National Geographic explorer, and fisherman based in Portland, Oregon. His photographs appeared in the October 2016 issue of the magazine.



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PHOTO: HANNAH WHITAKER

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‘MORE OFTEN THAN NOT, AFTER A SHORT USEFUL LIFE, PLASTIC OBJECTS EMBARK ON WHAT’S LIKELY TO BE A CENTURIES-LONG AFTERLIFE AS TRASH.’

CONTROVERSIAL DIGS UNDER THE HOLY CITY ARE REVEALING MILLENNIA OF RELIGIOUS AND CULTURAL TREASURES—AND STOKING AGE-OLD TENSIONS.

BY **ANDREW LAWLER**
PHOTOGRAPHS BY **SIMON NORFOLK**

UNDER JE



JERUSALEM

PREVIOUS PHOTO

Below the Church of the Holy Sepulchre in Jerusalem's Christian Quarter, Father Samuel Aghoyan views a quarry that was used as a Jewish cemetery during the time of Jesus. A nearby rock outcrop is venerated as Golgotha, the hill on which Christ was crucified.

RIGHT

To uncover a stepped street that served as a major route to the Jewish Temple 2,000 years ago, Israeli archaeologists and engineers are building what resembles a subway tunnel under a Palestinian neighborhood. Residents claim the dig has damaged homes above.

'DUCK DOWN' IS JOE UZIEL'S CONSTANT REFRAIN.

I'm struggling to keep up with the Israeli archaeologist as he slips his thin frame easily through the twisting and narrow tunnel studded with protruding rock. With only the light of our smartphones to guide us, I bend low to prevent my battered yellow hard hat from scraping the stone overhead. Then he stops abruptly. "I'm going to show you something cool."

The cramped passage lies beneath a rocky spur of land jutting south from Jerusalem's Old City. The narrow ridge, the site of early Jerusalem and today packed with houses occupied mostly by Palestinian residents, conceals a subterranean labyrinth of natural caves, Canaanite water channels, Judaean tunnels, and Roman quarries. This particular passage is of more recent vintage than most, having been hewed by two British archaeologists in the 1890s.

I follow Uziel into a recently excavated space that's the size and height of a comfortable suburban living room. His light picks out a stubby, pale cylinder. "It's a Byzantine column," he





Israeli soldiers listen to a tour guide at Jerusalem's Cardo Maximus, or Roman main street, where a mural depicts the busy colonnaded thoroughfare as it may have looked during Byzantine times, in the sixth century—minus the boy in a baseball cap (at bottom right).

explains, crouching down to pull back a lumpy sandbag, revealing a smooth white surface. "And this is a portion of the marble floor."

We are standing in a fifth-century church built to commemorate the site where Jesus is said to have cured a blind man near the Pool of Siloam. The sanctuary fell out of use, its roof eventually collapsed, and the ancient building over time joined the city's vast underground realm.

For Uziel the church is more than cool. It's also the latest complication in one of the world's most expensive and controversial archaeological projects. His mission is to unearth a 2,000-year-old, 2,000-foot-long street that once conveyed pilgrims, merchants, and other visitors to one of the wonders of ancient Palestine: the Jewish Temple. Choked with debris during the fiery destruction of the city by Roman forces in A.D. 70, this monumental path disappeared from view.

"Because of the church, we have to change direction," says Uziel. "You never know what you are going to hit." He already has bumped into Jewish ritual baths, a late Roman building, and the foundations of an early Islamic palace. Each has to be mapped and studied, and a detour found or a path made by removing the obstacle or drilling through the impediment.

When the British excavators burrowed their way into the church, tunneling was common. Today, except under special circumstances, it is seen as both dangerous and unscientific. Here, however, excavating from the surface down is impractical, given that people live just yards above. Instead, an army of engineers and construction workers, toiling 16 hours a day in two shifts, is boring a horizontal shaft under the spine of the ridge. As they move forward, Uziel and his team laboriously dig out earth from the top of each newly exposed section to the bottom, retrieving pottery, coins, and other artifacts. Whether this method is scientifically sound depends on which Israeli archaeologist you ask. For some it's revolutionary; for others it's deeply misguided.

Tunnel workers battle unstable soil that has led to cave-ins, while residents living above complain of damage to their homes. The ambitious project, funded largely by a Jewish settler organization, is in a particularly sensitive spot in East Jerusalem, the area of the city annexed by Israel in 1967 that much of the world considers occupied territory. (Most excavation in such territory is illegal under international law.)



Called Wadi Hilweh by Palestinians, for Jews this is the City of David, the place where King David created the first Israelite capital.

Uziel leads me back through the narrow passage, and we emerge into a completed portion of the new tunnel. In the sudden glare I'm almost clobbered by a plastic bucket filled with earth sailing by on an overhead conveyor belt. Unlike the dark and dank British shaft, this one is braced in shiny steel and resembles a subway line in size and shape. Instead of tracks, however, ancient limestone steps gleam into the distance. "Some of these stones seem virtually untouched," the archaeologist marvels as we stroll up the broad stairs. "This was the main street of early Roman Jerusalem. Pilgrims purified themselves at the pool and then made their way up to the Temple."

The path proved short-lived. Unearthed coins suggest that a notorious gentile oversaw construction of the monumental staircase around A.D. 30, a Roman prefect best known for ordering the Crucifixion of Jesus: Pontius Pilate.



The Freger family from Canada celebrates their daughter Adyson's bat mitzvah in an underground hall near Jerusalem's Western Wall, one of the holiest sites in Judaism. The vaulted chamber, built by Muslims in the 14th century as an inn for caravans, was transformed into a Jewish event space and linked to the warren of Western Wall tunnels.

HADAS PARUSH (BOTH PHOTOS)







Fans enjoy a concert in Zedekiah's Cave, a quarry that for millennia provided limestone for buildings above. Legends say Judaean King Zedekiah escaped through the cave in the sixth century B.C. and that King Solomon may have used its stone to build the first Jewish Temple.



"TRUTH SHALL SPRING OUT of the earth," say the Psalms, but whose truth is the question that haunts Jerusalem. In a city central to the three great monotheistic faiths, putting a spade into the ground can have immediate and far-reaching consequences. In few places on Earth can an archaeological excavation so quickly spark a riot, threaten a regional war, or set the entire world on edge.

After the Israeli government opened a new exit to an underground passage along a part of the Western Wall in the Old City's Muslim Quarter in 1996, some 120 people across the region died during violent protests. Subsequent squabbling over who should control what lies beneath the sacred platform that Jews refer to as Har HaBayit (the Temple Mount) and Arabs call Haram al Sharif (the Noble Sanctuary) helped scuttle the Oslo peace accord. Even the recent construction of Jerusalem's Museum of Tolerance has come under fire for destroying Muslim graves.

"Archaeology in Jerusalem is so sensitive that it touches not just the research community but politicians and the general public," acknowledges Yuval Baruch of the Israel Antiquities Authority (IAA). Baruch is chief of the IAA's busy Jerusalem office, and he's proud of his unofficial title as the mayor of underground Jerusalem. Under his reign the city has become one of the world's busiest archaeological sites, with around a hundred excavations a year.

Palestinian Authority president Mahmoud Abbas has complained that the constant digging is part of a campaign to overwhelm 1,400 years of Muslim heritage with Jewish finds. "Here archaeology is not merely about scientific knowledge—it is a political science," adds Yusuf Natsheh, director of Islamic archaeology for the Jerusalem Islamic Waqf, the religious foundation that oversees Jerusalem's Muslim holy sites.

Baruch hotly denies any bias in what's excavated. Whether Canaanite or crusader, each era gets its scientific due, he insists. There is no doubt that Israeli archaeologists are among the best trained in the world. Yet there's also no doubt that archaeology is wielded as a political weapon in the Arab-Israeli conflict, with Israelis having the edge since they control all excavation permits in and around Jerusalem. At a speech in 2011 before the United Nations General Assembly, the Israeli prime minister said he kept in his office a 2,800-year-old signet ring found near the Western Wall inscribed with his family's adopted surname, Netanyahu, citing it as a physical token of Jerusalem's Jewish past.

Politics, religion, and archaeology have long been deeply entwined here. Around A.D. 327, Byzantine empress Helena presided over the demolition of a Roman temple. "She opened up the earth, scattered the dust, and found three crosses in disarray," according to a nearly contemporary source. The elderly mother of Constantine the Great, she declared one to be the piece of wood on which Jesus was crucified. What was hailed as the True Cross, the most famous of Christian artifacts, helped spark interest in sacred Christian relics. The Church of the Holy Sepulchre soon rose over the site.

Some 1,500 years later, a French scholar and politician named Louis-Félicien Joseph Caignart de Saulcy launched the city's first archaeological excavation and sparked another craze. In 1863 he dug out a complex of elaborate tombs, enraging local Jews who filled in at night what his workers exposed in the day. Undeterred, de Saulcy hauled to the Louvre an ancient sa
containing the remains of what he cl
an early Jewish queen.

Other European explorers arriv
their own biblical treasures. In 1867
dispatched a young Welshman to pr
lem's underground terrain. Charles W
local crews to dig deep shafts and tu
kept his work from the prying eyes o
officials who then controlled Jerusa
digging proved difficult, he used dy
clear pockets of stone. Warren's as
exploits—he once explored a sewag
by laying old doors across the muc
remarkably precise maps are still a w
another legacy may be an enduring
archaeologists among the city's Mus

A century later, when Israel cap
Jerusalem, including the Old City,
forces during the 1967 Six Day W
archaeologists launched major scie
vations that became a centerpiece of



Splashes and laughs top off a trek through Hezekiah's Tunnel, which channels water some 600 yards from the Gihon Spring—ancient Jerusalem's main water source—to this pool. King Hezekiah, the Bible says, built the tunnel to protect the city's water supply from invaders.
HADAS PARUSH

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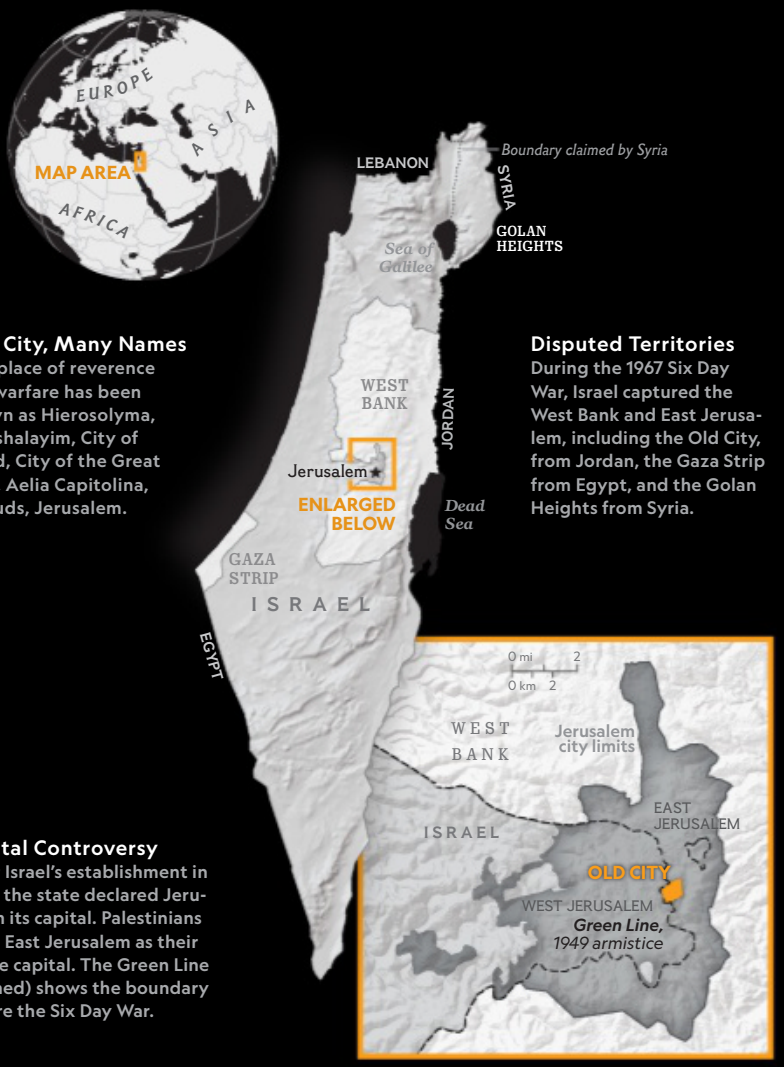
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country's efforts to prove and celebrate its ancient roots. They unearthed first-century villas of the Jewish elite filled with elegant mosaics and painted walls. But they also exposed parts of the long-lost Nea Church that had been built 500 years later and was second in importance only to the Holy Sepulchre, as well as ruins of an enormous complex constructed by early Muslim rulers.

Some excavations, however, were overtly religious. Only a few segments of the Western Wall—a remnant of Herod the Great's Temple platform and Judaism's most sacred site where Jews can pray—are aboveground, so after the Six Day War, the Ministry of Religion began an effort to expose its entire length by digging tunnels. Longer than the Empire State Building is tall, the wall is covered by later buildings along more than half its length. For almost two decades there was little archaeological supervision of the tunnel work, and untold data were lost, says Israeli archaeologist Dan Bahat, who

HOLY TO JEWS, CHRISTIANS, AND MUSLIMS, MODERN JERUSALEM HAS BEEN SHAPED BY 3,000 YEARS OF WORSHIP, CONQUEST, DEVASTATION, AND REBUILDING.

BY ALBERTO LUCAS LÓPEZ
AND MATTHEW W. CHWASTYK



One City, Many Names
This place of reverence and warfare has been known as Hierosolyma, Yerushalayim, City of David, City of the Great King, Aelia Capitolina, Al Quds, Jerusalem.

Disputed Territories
During the 1967 Six Day War, Israel captured the West Bank and East Jerusalem, including the Old City, from Jordan, the Gaza Strip from Egypt, and the Golan Heights from Syria.

Capital Controversy
After Israel's establishment in 1948, the state declared Jerusalem its capital. Palestinians claim East Jerusalem as their future capital. The Green Line (dashed) shows the boundary before the Six Day War.

CONTESTED HERITAGE

JERUSALEM'S ERAS OF BUILDING

SACRED MOSAIC

The embattled Old City of Jerusalem has grown over the centuries into an architectural patchwork reflecting the styles, beliefs, and priorities of conquerors past. The rulers who rebuilt or repurposed these structures are long gone, but evidence of their ambitions remains—both above and deep below the bustling metropolis.

SITES BY HISTORIC ERA
Color represents latest period of construction

Underground ABOVEGROUND

- Israeli control *1967-today*
- Jordanian control *1948-1967*
- British Mandate *1917-1948*
- Ottoman *1517-1917*
- Ayyubid and Mamluk *1187-1517*
- Crusader *1099-1187*
- Early Islamic *(Umayyad, Abbasid, Fatimid) 638-1099*
- Byzantine *324-638*
- Herodian and Roman *63 B.C.- A.D. 324*
- Persian, Hellenistic, Hasmonean *538 B.C.-63 B.C.*
- Iron Age *(Israelite, Assyrian, Babylonian) ca 1200 B.C.-538 B.C.*
- Bronze Age *(Canaanite, Jebusite) before 1200 B.C.*
- Archaeological site *(several eras)*
- Date unrecorded

Tunnel *Cistern* *Church* *Synagogue* *Mosque*

TOWER OF DAVID CITADEL
Mamluk and Ottoman fortifications stand over earlier towers built by Hasmonean Jews and Herod the Great. The site played a role in the city's defense for 2,500 years.

CHURCH OF THE HOLY SEPULCHRE
Begun in the Roman period, the church is honored as the site where Jesus Christ was crucified and buried, and then rose from the dead.

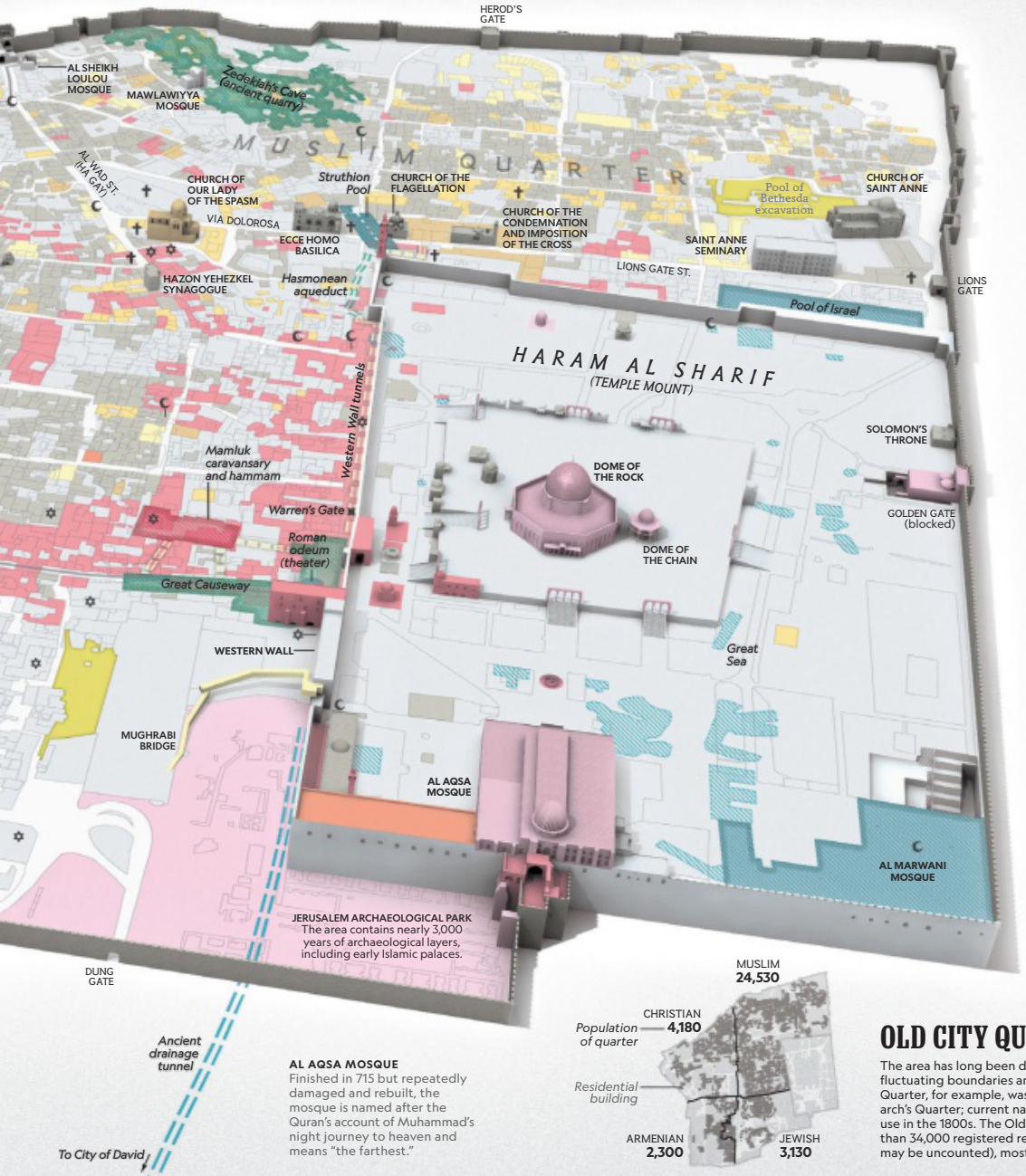
DAMASCUS GATE
NEW GATE
QAYMARI MOSQUE
SAINT SAVIOUR CHURCH
EL KHANQA MOSQUE
Patriarch's Hall (crusader-period cellar)
SAINT ANTHONY'S CHURCH AND MONASTERY
VIA DOLOROSA
CHRISTIAN QUARTER
CHURCH OF THE HOLY SEPULCHRE
Chapel of the Finding of the Cross
LATIN PATRIARCHATE ST.
JAFFA GATE
SAINT GEORGE CHURCH
Hezekiah's Pool
CHRISTIAN QUARTER ST.
EL OMARIYA MOSQUE
SAINT ALEXANDER NEVSKY CHURCH
CHURCH OF THE REDEEMER *(Byzantine excavation beneath)*
Tower of David
CHURCH OF SAINT JOHN THE BAPTIST
DAVID ST. (SUQ EL BAZAR)
THE CITADEL (AL QALA)
CHRIST CHURCH
HA SHALSHELET (STREET OF THE CHAIN)
Kishle excavation
Beneath the Ottoman-era structure lie the foundations of King Herod's palace.
Israelite tower
MENACHEM ZION SYNAGOGUE
Broad wall
JEWISH QUARTER
Cardo Maximus
Roman legionary bath
CATHEDRAL OF SAINT JAMES
ARMENIAN SEMINARY
HABAD SYNAGOGUE
Burnt house
HURVA SYNAGOGUE
ARMENIAN QUARTER
HABAD ST. (SUQ EL HUSSOR)
ELIYYAHU HANAVI, EMTSAI, JOHANAN BEN ZAKKAY, ISTANBULY SYNAGOGUES
Herodian-elite mansions
The richly mosaicked buildings reveal lifestyles of the wealthy before the Romans laid waste to the city.
N
SCALE VARIES IN THIS PERSPECTIVE.
ARMENIAN PATRIARCHATE ST.
CHURCH OF THE HOLY ARCHANGELS
AL DISI MOSQUE
Nea Church vaults, cellar, and cisterns
ZION GATE

SHIFTING STRATEGIES

Fortifications to protect the city have been built and torn down over millennia. Ayyubid Muslims destroyed the walls in 1219 for easy recapture if Jerusalem was lost again to crusaders; Ottoman-era ramparts now enclose 224 acres of the Old City.



Nea Church
Commissioned by Byzantine emperor Justinian in 543, this basilica rivaled others in the empire for beauty and importance. Centuries later, the church fell into disuse and its location was covered by newer construction.



Pool of Bethesda
Archaeologists have dated structures at this site, under and around the Church of St. Anne, to Roman, Byzantine, and crusader periods.

VIA DOLOROSA
Running from Lions Gate Street into the Church of the Holy Sepulchre, the traditional Crucifixion route of Jesus is marked by 14 stations of the cross that recount his ordeal.

Western Wall tunnels
Tracing the foundation of Herod's Temple Mount, visitors can see Warren's Gate, now the closest point in the tunnels to the holiest part of the old Temple site.

DOME OF THE ROCK
Begun in 691, this shrine protects bedrock venerated as the place where Abraham was to sacrifice his son and Muhammad ascended into heaven. Crusaders converted it into a church called Templum Domini.

WESTERN WALL
Herod's massive expansion of the Temple Mount required new foundation walls; the most intact, western one is now a hallowed site.

AL MARWANI MOSQUE
Now a mosque, this system of support arches was devised in the Herodian era. During the Crusades, Templar knights called it Solomon's Stables.

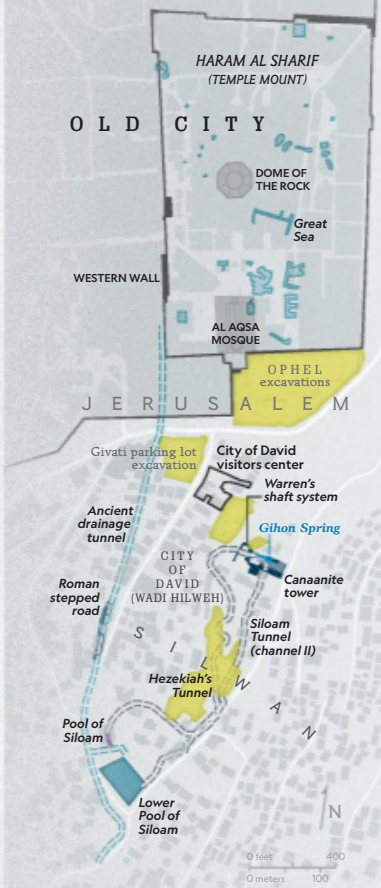
AL AQSA MOSQUE
Finished in 715 but repeatedly damaged and rebuilt, the mosque is named after the Quran's account of Muhammad's night journey to heaven and means "the farthest."

OLD CITY QUARTERS

The area has long been divided into quarters with fluctuating boundaries and names. The Christian Quarter, for example, was once called the Patriarch's Quarter; current names came into common use in the 1800s. The Old City is home to more than 34,000 registered residents (thousands more may be uncounted), most in the Muslim Quarter.

KING DAVID'S PALACE?

The Palestinian neighborhood of Silwan lies over a potential site for King David's palace, which would date to the 10th century B.C. Residents share hilly terrain with the archaeological excavations of the City of David National Park. A newly accessible underground route follows an ancient drain and stepped road from the Pools of Siloam to the Old City.



ALBERTO LUCAS LÓPEZ, MATTHEW W. CHWASTYK, AND KAYA BERNE, NGM STAFF; PATRICIA HEALY; GURA BERGER. 3D ART: ARIEL ROLDÁN

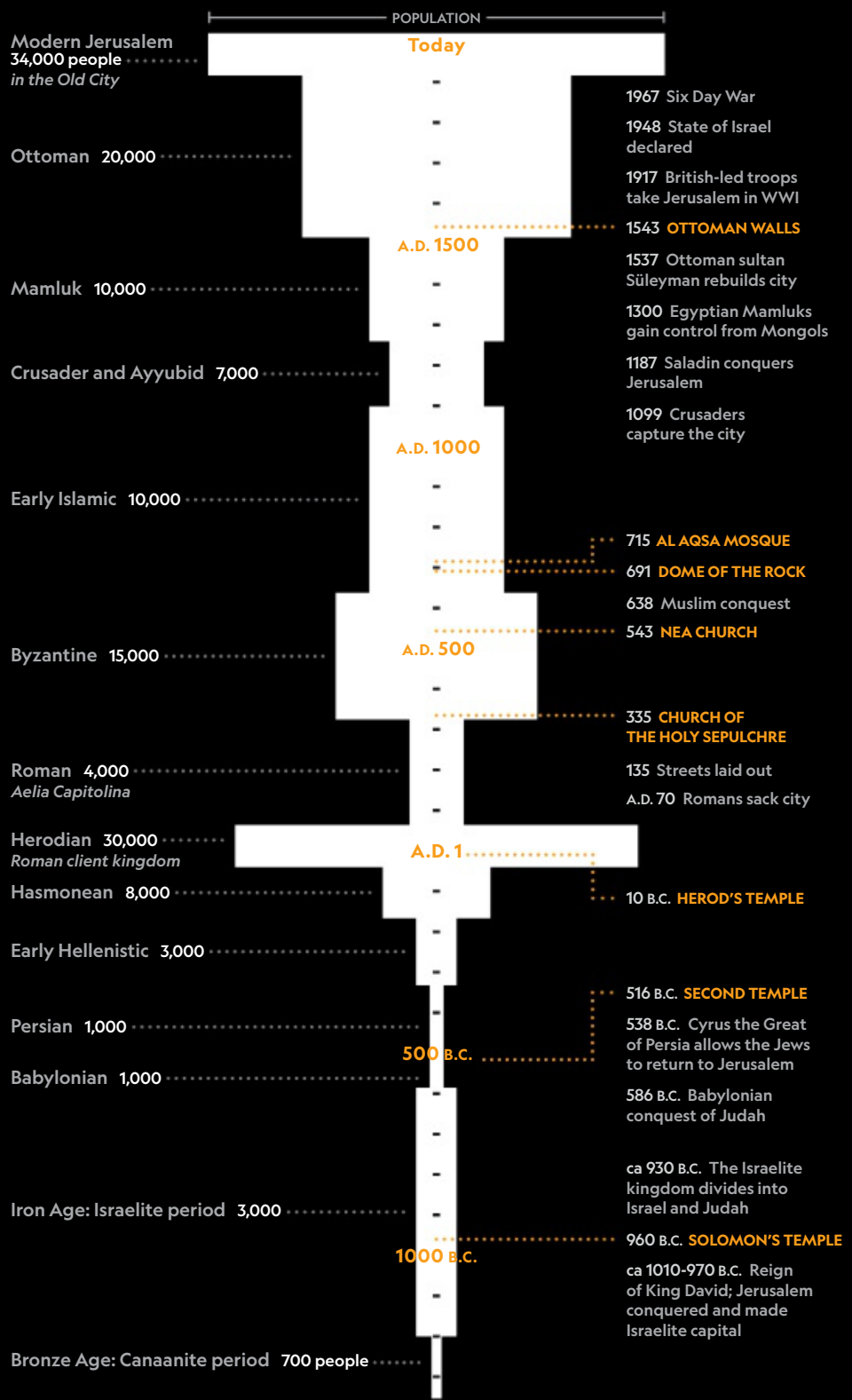
SOURCES: RIWAQ ARCHIVE, PALESTINIAN TERRITORIES (BUILDING PERIODS); JOE UZIEL, IAA; WENDY PULLAN, UNIVERSITY OF CAMBRIDGE, ENGLAND; JODI MAGNESS, UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL; JERUSALEM INSTITUTE FOR POLICY RESEARCH; JERUSALEM STATISTICAL YEARBOOK; HEBREW UNIVERSITY OF JERUSALEM GIS LAB; OPENSTREETMAP CONTRIBUTORS, AVAILABLE UNDER OPEN DATABASE LICENSE

JERUSALEM'S PEOPLE ...

The width of the bar shows the peak of the population estimate for that period; height indicates duration.

AND STRUCTURES

Orange indicates when key buildings in the time line were dedicated or opened for use.







A wall of photographs screens a former parking lot where archaeologists unearthed a clay seal impression linked to the biblical King Josiah—yet more proof, some say, of Jerusalem's ancient Jewish roots. Some Palestinians charge that archaeology is being used as a weapon of occupation.

HADAS PARUSH

agitated successfully for archaeological control over the digs. The work also fed Muslim suspicions that the real Israeli goal was to penetrate the wall and access the sacred platform.

One summer morning in 1981, just after *Raiders of the Lost Ark* opened in theaters, those suspicions were confirmed. Guards from the waqf encountered a prominent rabbi knocking down a crusader-era wall that sealed an ancient subterranean gate beneath the sacred platform. The rabbi believed the lost ark was secreted beneath the Dome of the Rock, one of Islam's oldest and holiest shrines. An underground scuffle ensued, and Israeli prime minister Menachem Begin quickly ordered the gate sealed before the conflict could morph into a full-fledged international crisis.

Fifteen years later, it was the turn of Israeli Jews to express outrage. In 1996 the waqf turned one of Jerusalem's most impressive underground spaces, an enormous columned hall beneath the southeastern end of the platform known as Solomon's Stables, from a dusty storeroom into the large Al Marwani Mosque. Three years later, the Israeli prime minister's office granted a waqf request to open a new exit to ensure crowd safety—Israel controls security on the platform—but without informing the IAA.

Heavy machinery quickly scooped out a vast pit without formal archaeological supervision. "By the time we got wind of it and stopped the work, a huge amount of damage had been done," recalls the IAA's Jon Seligman, then in charge of Jerusalem archaeology. Nazmi Al Jubeh, a Palestinian historian and archaeologist at Birzeit University, disagrees. "Nothing was destroyed," he says. "I was there, monitoring the digging to be sure they did not expose archaeological layers. Before they did, I yelled, *'Khalas!'*"—Enough! in Arabic.

Israeli police later hauled the resulting tons of earth away. In 2004 a privately funded sifting project started sorting through the dirt and has so far recovered more than half a million artifacts. When I visit the project's lab, archaeologist Gabriel Barkay pulls out cardboard boxes containing chunks of colored marble he believes came from courtyards surrounding the Jewish Temple. Seligman and many of his colleagues, however, dismiss the finds as having little value, since they were discovered out of context and might have been deposited on the platform in later periods. "The paradox," he adds, "was

Arafat Hamad sits among the ruins of his outdoor kitchen, which he says collapsed when Israeli archaeologists tunneled beneath his home. Hamad and his Palestinian neighbors complain of costly damage, but tunnel builders insist that their engineering is sound.

MANY PALESTINIANS BELIEVE THE JERUSALEM EXCAVATIONS AND ATTEMPTS TO DISPLACE THEM ARE INTIMATELY CONNECTED.



that most of what was destroyed by the waqf was Islamic."

ON A DRIZZLY WINTER morning I make my way to the entrance of the Western Wall tunnels, just off the plaza dense with men in black hats and coats. Inside is a jumble of underground reception halls, prayer areas, and archaeological excavations. Down the hall from a glass-and-steel synagogue cantilevered within a medieval Islamic religious school are Roman latrines and a recently unearthed small theater—the first found in ancient Jerusalem—built as part of the second-century revival of the city as Aelia Capitolina.

At a plywood door covering a stone arch, I meet Shlomit Weksler-Bdolah. She speaks as fast as she moves. "Come, come. I must get back down," the IAA archaeologist says as she trots down stairs that smell of freshly sawed wood. In the humid chamber below, three young Arab men in T-shirts casually maneuver a two-ton stone dangling from iron chains. Weksler-Bdolah explains that it's being moved to give tourists access to what she argues were formal banquet rooms built during the rule of Herod the Great.

"We are standing in the western triclinium"—a Roman term for a dining area with couches—"and the eastern hall is just beyond that passage," she says while keeping an eye on the gently swaying rock. According to her research, the elegant compound was built in the first century B.C. to wine and dine important visitors in grand fashion. Hidden lead pipes spouted water to create a pleasing ambience.

Weksler-Bdolah excuses herself when an engineer in a white helmet calls out from above. They have a long and heated discussion over a section of yellow plaster that he wants to remove to accommodate a metal stairway for tourists. "This is Roman-era plaster and very unusual," she says to me in an aside. These are the sort of debates that echo regularly beneath the streets of Jerusalem: What should remain, and what should be sacrificed?

A CENTURY AND A HALF of discoveries under Jerusalem have upset old beliefs and dashed cherished myths. Many archaeologists today dismiss the biblical vision of King Solomon's glittering capital of a large empire. The famous monarch is not even mentioned in any archaeological find of the era. Early Jerusalem was more likely a minor fortified hill town. Nor did the arrival of Islam in the seventh century A.D. suddenly displace Christianity, as historians long assumed. Many excavations show little change in the day-to-day life of Christian residents.



Yet the digs have unearthed clay seal impressions bearing the names of biblical courtiers, lending credibility to their existence. Archaeological work also backs Empress Helena's assertion that Jesus was crucified and buried on land that is within what is now the Church of the Holy Sepulchre. And archaeologist Eilat Mazar of the Hebrew University of Jerusalem even claims to have found the palace of King David, the first Israelite ruler of Jerusalem.

One quiet Saturday morning, the Jewish Sabbath, I run into Mazar as she wanders through the otherwise deserted City of David park. On the northeastern edge of the narrow ridge, she excavated a building with thick walls next to an impressive stepped stone structure that braces



Inside the underground Al Marwani Mosque, Muslim men await the start of Friday prayers. In 1999 workers used bulldozers to open a wide new entrance, raising fears that historical layers on the sacred platform had been damaged.

FAIZ ABU RMELEH

the steep slope. Based on the pottery she found, Mazar dates the building to around 1000 B.C.—the traditional date assigned to the Israelite takeover of Jebusite Jerusalem.

She is so deep in thought that I have to call her name twice to bring her out of her reverie. "I like to come here when it is quiet to think," she explains. She invites me down steps that lead to a metal catwalk above her famous excavation. She leans over the rail and points at the rubble below. "This was an extension of the old Canaanite palace, but the building is something new. This is a king with a vision, who built something large and impressive in a skilled manner." For Mazar, that can only be King David. "Everything fits the story in the Bible."

Her 2005 discovery made headlines around the world, but colleagues remain mostly unconvinced. She relies heavily on pottery for dating, rather than more modern methods such as radiocarbon, and her literal reading of the Bible is seen by many archaeologists as flawed. Even the sign on the catwalk adds a question mark to the identification of the site: "The remains of King David's palace?"

"I rely on facts," she says, a touch of irritation in her voice when I raise the objections of other academics. "What people believe is a different story. It takes time for people to accept what's new. I can't wait."

Mazar is eager to dig just to the north, where she believes the famous palace of David's son, Solomon, lies hidden. "I am sure it is there," she says with a sudden fierceness. "We need to excavate this!"

She's preparing a request for permission to dig the site. Whether the IAA will approve her further excavation is in question. "Today, if you dig, you need solid data—not just coins or pottery, but results using physics and biology,"


מגדל דוד
Tower of David
ISRAEL POLICE



The gleaming Dome of the Rock, an Islamic shrine built in the seventh century, is impossible to miss from this overlook above the Western Wall plaza. Virtual reality headsets remove the shrine and many other layers of the city to transport tourists to first-century Jewish Jerusalem.

says the IAA's Baruch. "Eilat Mazar is not playing in this game."

ACROSS THE STREET from Mazar's putative palace of David, Yuval Gadot epitomizes this new game. The tall and affable Tel Aviv University archaeologist once opposed Israeli digs in this overwhelmingly Palestinian neighborhood, but the opportunity to lead the city's largest recent excavation proved too tempting to refuse. What once was a dusty parking lot is now an enormous pit open to the sky, encompassing much of the city's past 2,600 years, from early Islamic workshops and a Roman villa to impressive Iron Age buildings predating the Babylonian destruction of 586 B.C. Much of the work takes place in off-site labs, where specialists analyze everything from ancient parasites in Islamic cesspits to intricate gold jewelry from the days of Greek rule.

Soon the excavation will open to the public, beneath a large new visitors center to accommodate the increasing hordes of tourists. Gadot, Mazar, and Uziel have helped turn this quiet Arab village into one of Israel's most popular attractions in a city rated among the world's fastest growing tourist destinations. At night their archaeological sites serve as dramatic backdrops for laser light shows.

"Here it began, and here it continues," thunders the narrator amid colored lights and swelling music. "The return to Zion!"

The organization behind this effort is the City of David Foundation. Created by former Israeli military commander David Be'eri in the 1980s to establish a strong Jewish presence, it has funded the lion's share of recent archaeology here. Along with deep pockets provided by foreign and Israeli donors, the group boasts excellent political connections. At a lavish ceremony last June, U.S. ambassador David Friedman swung a hammer to break a wall, inaugurating the first segment of Uziel's tunnel. "This is the truth," he said of the ancient street. The White House Middle East envoy called Palestinian criticism of the event "ludicrous."

When I meet with the foundation's vice president, Doron Spielman, he is bullish about the future. "If the next 10 years are like the last 10 years, this will be the number one archaeological spot in the world," says the Jewish native of the Detroit suburbs. Spielman expects the visitor tally to nearly quadruple to two million in a decade. "There is a fascination for a people who

WHAT WAS A PARKING LOT IS AN OPEN PIT WITH 2,600 YEARS OF HISTORY: EARLY ISLAMIC WORKSHOPS, A ROMAN VILLA, AND IRON AGE BUILDINGS.

have existed for thousands of years," he says. "This isn't like an Akkadian site. The people who began here are still here."

In his telling, the development helps everyone. "People buy their Popsicles and drinks from Arab stores," he says. "And there is a lot of security that benefits both Arabs and Jews." He is also optimistic about the impact of Jewish residents, who now number about one in 10 and who live largely in gated compounds patrolled by armed guards. "You will see this as a model of coexistence. People will be living together within an active archaeology site with a lot of opportunity."

THAT'S NOT HOW Abd Yusuf, a burly local shopkeeper, sees it. "Business is terrible!" he tells me, as he sits amid Jerusalem-themed knickknacks. "We used to have so many tourists, but now no one comes. They take all the tourists to their shops," he adds, referring to the City of David's concessions. Then he points to cracks in his wall. "I have had to replace my door three times because the earth shifts beneath."

Just up the street, I pay a visit to Sahar Abbasi, an English teacher who also works as deputy director at the Wadi Hilweh Information Center, a Palestinian organization housed in a modest storefront. "The excavations pose many challenges," she says. "Our homes are being damaged and destroyed." She estimates that 40 houses have been affected, half of them severely, while five families have been evicted from dwellings considered unsafe.

"If they can't control us from above, they start to control us from below," Abbasi adds.

One morning, off a narrow alley above Uziel's tunnel, Arafat Hamad welcomes me into his courtyard studded with lemon trees. A retired barber, Hamad has short silver hair and a fast smile that fades quickly. "I built this house in 1964 with a thick concrete foundation, but look what has happened in the past couple of years," he says, pointing to wide cracks that creep up to just below the first-floor windows. Taking me around to the side of the house, Hamad points to piles of rubble. "One evening last August we were sitting on the porch when the house began to shake," he recalls. "We could hear them working below with heavy machinery. If you put your hand to the floor, you could feel the vibrations. We fled the house to neighbors', and then we heard a bang—and we could see the cloud of dust rising from where our outdoor kitchen had been."

Across the street, Hamad's neighbor, an older woman named Miriam Bashir, doesn't seem happy to see me. "I'm fed up with journalists," she says. "I just want to be left alone. We are lost. We don't know what to do!"

After a few minutes she relents and agrees to show me the damage to her interior walls. "The cracks began three years ago, but they became more obvious in the past year and a half," she says. As I say goodbye to Bashir at her gate, she smiles for the first time. "I would like you to relate our story in an honest and clear way. We are peaceful people who live here, and we will stay here despite the damage."

When I spoke with Spielman, he dismissed the concerns of Arab residents. "Yes, we are working under people's homes, which is not an issue if it is engineered well, which it is."

Three days after my visit to the Palestinians, Spielman sent a chilly email warning me against providing a stage for "the claims of politically motivated, anti-Israel, special interest groups." He requested that I supply in writing the details of any "nefarious claims" before publication. My repeated attempts to speak again with him and other City of David officials were met with silence. The waqf's Natsheh is not so reticent. For him the excavations and attempts to displace Palestinians are intimately connected. "Archaeology should not be a tool for justifying occupation," he says.

What lies beneath Jerusalem reveals that the city's history is too rich and complicated to fit any single narrative, whether Jewish, Christian, or Muslim. Helena failed to wipe away its pagan past, just as the Romans fell short of annihilating the rebellious Judaean capital and Muslims couldn't remove all traces of the hated crusader occupation. No matter who is in charge of this most contested of places, evidence from the past inevitably will surface, challenging any story tailored to a narrow political or religious agenda.

"Everyone who ruled Jerusalem did the same thing: built his tower and hoisted his flag," says Weksler-Bdolah with a laugh, taking the long view demanded by this venerable and violent place. "But I think it is stronger than all those who try to control it. No one can completely erase what came before." □

Andrew Lawler wrote about the Lost Colony of Roanoke in the June 2018 issue of *National Geographic*. Photographer **Simon Norfolk** has documented many of the world's conflict zones.

OUR ADDICTION TO PLASTIC

HOW CONVENIENT, DISPOSABLE PLASTIC OBJECTS CAME TO DOMINATE OUR DAILY LIVES—AND HOW WE MIGHT BREAK THE HABIT, FOR THE PLANET'S SAKE

PHOTOGRAPHS BY **HANNAH WHITAKER**



BILLIONS

of plastic utensils are thrown away each year around the world. How did we ever get along without them—and could we again?

It might be hard at first glance to see what things like toothbrushes, tires, cigarettes, and shoes have in common.

But look closer and you'll find that, like so many objects in our daily lives, they're often made to a greater or lesser extent of the miracle stuff: plastic.

That stuff is now a planetary problem. Sometimes, because the plastic is mixed with other materials—including other plastics, such as in shoes—it's difficult or impossible to recycle. In many places, recycling, incineration, or disposal in a landfill isn't an option, not to mention all the litter that ends up in rivers and oceans. And so, more often than not, after a short useful life, plastic objects embark on what's likely to be a centuries-long afterlife as trash.

They're thrown into rivers and wash into the sea. They break down into tiny bits called microplastics. Marine creatures big and small eat those particles. Pieces get mixed in with sea salt and we wind up eating them, with uncertain effects. We breathe in even smaller particles, called nanoplastics: Scientists recently discovered them on remote mountaintops and even in the Arctic, where they are carried by winds and mixed with rain and snow.

The miracle has now become the stuff of nightmares.

Increasingly the challenge is to have the former without the latter. "Reduce, reuse, and recycle" has been the environmentalists' answer for half a century. Businesses that sell plastic products or packaging, however, have little incentive to encourage reducing or reusing, and recycling—once thought a panacea—can be complicated and expensive. But with plastic pollution now a global problem, the stakes are raised, and so is public awareness.

A cultural shift seems to be in the offing. Plastic waste has started to worry us. Entrepreneurs are creating new options for avoiding it. The point is not to demonize things that were invented for good reason and with good intentions; the point is to find a way to have our plastic and not eat it too.

Every facet of our lives that has been touched by plastic presents a different challenge. Every object has a story. Here are a few of those stories—and some solutions. —LORI CUTHBERT

The nonprofit National Geographic Society helped fund this article.

1 MILLION

plastic beverage bottles are bought every minute around the world. Yet recycling rates remain low.

Planet or plastic?

National Geographic is committed to reducing plastics pollution. Learn more about our nonprofit activities at *natgeo.org/plastics*. This story is part of Planet or Plastic?—our multiyear effort to raise awareness about the global plastic waste crisis. Learn what you can do to reduce your own single-use plastics, and take the pledge.

Find out more about the plastic products featured here in videos and articles at *natgeo.com/plastic*.

ALL PROP STYLING: HEATHER GREENE



24.2 BILLION

pairs of shoes were made worldwide in 2018. Shoes are hard to recycle because different types of plastic and other materials are glued and molded together.







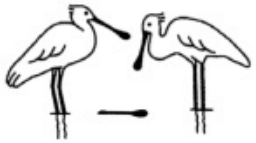
1
BILLION

toothbrushes will be discarded in the U.S. this year. There are biodegradable alternatives, but plastic toothbrushes prevail.



60
MILLION

tires are rotting in U.S. landfills. They shed a lot of their plastic and rubber beforehand—in tiny bits as the tires rub against the road.



DISPOSABLE CUTLERY

PLASTIC ADDED 1940s

PLASTIC CUTLERY is everywhere. Like plastic straws, billions of forks, knives, and spoons are used, then thrown away, each year. And like most plastic, cutlery can take centuries to break down naturally, giving the pointy and sharp-edged objects ample time to reach the sea. Disposable utensils, mostly made of polystyrene, are considered among the items most deadly to sea turtles, birds, and marine mammals.

When plastic cutlery first came on the scene during World War II, it was considered as reusable as the metal it replaced, safe after a good washing. But plastic is much cheaper, and as the frugal war mentality faded, so did the urge to reuse. In the 1970s, inventions like the plastic spork and an all-in-one picnic plate and cup holder gave people even more utensils to throw away. Cutlery is now the seventh most commonly collected plastic item during beach cleanups. (Food wrappers, bottle caps, and beverage containers are at the top by far.)

Several companies are creating utensils from alternative materials such as wood from fast-growing birch or bamboo, or from excess lumber. A back-to-the-future "bring your own cutlery" movement is gaining steam as well. In France, a nation of picnickers, a ban on plastic utensils takes effect in 2020.

— TIK ROOT

THINGS YOU CAN DO TO HELP

1. Carry reusable cutlery.
2. If you use disposable cutlery, make sure it's biodegradable or compostable.
3. Eat at establishments that don't use plastic utensils.

BOTTLES



Of all plastic products, the beverage bottle stands out because of how quickly it became ubiquitous and changed drinking habits. In the 1960s Americans and others bought beverages in glass bottles or aluminum cans. Polyethylene terephthalate, or PET, changed the game: Light enough to slash transportation costs, PET bottles were strong enough to keep drinks fizzy. Bottled water, common in Europe, began conquering the U.S. market in the late 1970s. Although bottled water costs up to 10,000 times more than tap water, global sales surpassed soft drink sales in 2016. Today a million plastic beverage bottles are bought every minute.

PLASTIC ADDED 1973

PET is recyclable, but recycling rates remain low. In 2016 fewer than half the bottles bought worldwide were collected. In the U.S., new PET bottles have only 7 percent recycled content. Discarded bottles break down into microplastics, and scientists are studying the full extent of harm those tiny bits cause to us and wildlife.

The plastics and beverage industries have fought bottle deposits because of increased costs. But from Kenya to India, bottle bans are being considered. Public drinking fountains are reemerging: A hundred are planned in London. Entrepreneurs and businesses are finding ways to reuse plastics, including ink cartridges and clothes. And in Nova Scotia, Canada, a three-bedroom house recently was built out of some 600,000 bottles.

— LAURA PARKER

THINGS YOU CAN DO TO HELP

1. Carry a reusable bottle.
2. Choose aluminum cans when possible.
3. Recycle all plastic bottles.

TOOTHBRUSHES

PLASTIC ADDED 1930s

PLASTIC HAS SO FULLY infiltrated toothbrush design that it's nearly impossible to clean our teeth without touching the stuff. Handles typically are made of polyethylene or polypropylene, the bristles of nylon. And because plastic takes so long to degrade, nearly every toothbrush made since the 1930s is still out there in the world somewhere, continuing on as a piece of trash.

Teeth cleaning is an old and universal habit. Archaeologists have found "tooth sticks" in the tombs of Egyptian pharaohs; across Asia and the Middle East, people chewed sticks into fluffy-ended scrubbers. In the late 1400s a simple design emerged from China and endured, essentially unchanged, for centuries: a short, dense pack of bristles cut off a hog's neck, set into a bone or wood handle. In Europe, only the wealthy could afford such marvels until the mid-1800s.

IN A 2003 SURVEY THE TOOTHBRUSH RATED HIGHER THAN CARS AND CELL PHONES AS THE INNOVATION PEOPLE COULDN'T DO WITHOUT.

The U.S. military helped bring dental care to the masses. Civil War soldiers needed to bite the thick paper wrapping off bullets, and without good teeth—or at least some teeth—U.S. Army troops couldn't eat the dry military rations they were provided. The military "had a standard, and it's pretty basic—have six teeth in your mouth so you can chew," historian Alyssa Picard says.

Soldiers coming home from World War II brought their military-issued toothbrushes with them, and cheap and moldable plastic made it possible for all Americans to embrace better dental hygiene. In a 2003 MIT survey of public opinion on innovations, the toothbrush rated higher than cars, personal computers, and cell phones as the one respondents couldn't live without.

If only the price of healthy teeth wasn't an imperishable piece of waste.

"I like to ask people, what's the first thing you touch in the morning? It's probably your toothbrush," says Kahi Pacarro, founder of Sustainable Coastlines Hawaii, who has plucked quite a few toothbrushes off Hawaiian beaches. "Do you want the first thing you touch every day to be plastic?" Some designers are now incorporating natural materials. Handles can be made of metal or bamboo; bristle heads can be replaced, and bristles packed more densely for longer lives. Toothbrushes of the future may still use plastic, just less of it.

— ALEJANDRA BORUNDA



THINGS YOU CAN DO TO HELP

1. Try out bamboo brushes—and compost the handle after pulling out the plastic bristles.
2. Choose a toothbrush with a replaceable head.
3. If your dentist gives out free toothbrushes, ask for nonplastic options.

SHOES

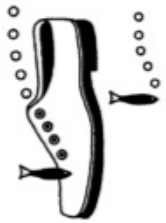
More than 24 billion pairs of shoes were made worldwide in 2018; some 2.4 billion pairs were sold in the U.S. alone. With an average of seven new pairs of shoes per person last year, closets across the U.S. are exploding with footwear. Plastic was introduced to shoes in the 1950s. Today most sneakers are partly or all plastic, from the squishy foam sole to the polyester upper, and we can thank plastics for the profusion of stilettos too.

Materials are stitched and glued and molded together in complicated ways, so shoes are almost impossible to recycle. Our feet are only a short stop in shoes' long lifetimes, mostly spent in landfills and waterways.

PLASTIC ADDED 1950s

Plastics have made shoes lighter, faster, cheaper, and more comfortable; they enabled the boom in recreational running. Reining in their use won't be easy. Some companies are making shoes out of recycled plastic, or from natural materials like bamboo and wood. Leather is natural too, but some people object to animal products.

— ALEJANDRA BORUNDA



THINGS YOU CAN DO TO HELP

1. Repair shoes as often as possible.
2. Buy fewer pairs of shoes.
3. Donate rather than discard old shoes.

ILLUSTRATIONS BY PABLO AMARGO



TIRES

PLASTIC ADDED 1909

Most of us use tires daily in one way or another, but we may not be aware that they add a lot to plastic pollution. As they rub against the road, tires throw off bits of synthetic rubber, which, like other plastics, is a petroleum-derived polymer. Rain washes those plastic bits off the road and into streams. By one estimate, tires could account for as much as 28 percent of the microplastic waste reaching the ocean.

Once upon a time, rubber came only from trees. But then more people started driving, and the world needed more rubber than nature could give. In 1909 German chemist Fritz Hofmann invented the first commercial synthetic rubber. Shortly after, it was in car tires. By 1931 DuPont had industrialized the manufacture of synthetic rubber.

Today tires consist of about 19 percent natural and 24 percent synthetic rubber. The rest is metals and other compounds. The modern radial tire hasn't seen a major redesign in decades, but lately there has been a push to develop more sustainable options. Researchers led by the University of Minnesota, for example, recently found a way to produce a key ingredient in synthetic rubber with carbon-neutral sources such as trees, grass, and corn.

Last year, Goodyear unveiled a concept tire made from recycled rubber that has living moss in the sidewalls. The moss is supposed to soak up carbon dioxide.

None of that keeps a tire from shedding microplastics. Maybe road surfaces could be made less abrasive without making them more slippery. Maybe microplastic-laden runoff could be captured before it ends up in the ocean.

The tire problem has been recognized only recently, so the search for solutions is just starting. But it's clear that there's a need for further research and increased public awareness.

— TIK ROOT

THINGS YOU CAN DO TO HELP

1. Reduce the amount you drive by carpooling.
2. When replacing tires, check that old ones are recycled.
3. Take public transportation whenever possible.

CIGARETTES

PLASTIC ADDED 1950s

TRILLIONS OF CIGARETTES are sold worldwide every year. Yet only about one-third of cigarette butts end up in the trash. The rest are flicked into streets and waterways and make their way to the sea, where they leach nicotine and tar into the environment—along with plastic, because that's what filters are made of. Cigarette butts are one of the top plastic items found on beaches.

"There's something about flicking that cigarette butt," says Cindy Zipf, executive director of Clean Ocean Action. "It's so automatic."

The plastic is cellulose acetate, the same material that's in photographic film. In the ocean it breaks down into microplastics. But before then, marine animals often mistake the butts for prey. "They look a lot more like a morsel of food on the sea surface," Zipf says.

In the first half of the 20th century, the number of smokers in the U.S. exploded, as did the incidence of lung cancer and other smoking-related health problems. Companies developed filters in the 1950s, purportedly to reduce the carcinogens in smoke. The irony is they don't seem to reduce cancer deaths; we may be deriving no real benefit from filters before they're carelessly discarded.

FILTERS DON'T SEEM TO REDUCE CANCER DEATHS, BUT DO FOUL THE ENVIRONMENT.



Now beaches are starting to get hit by the latest smoking technology: electronic cigarettes. More than 10 million U.S. smokers use e-cigarettes, and many people treat them like filtered cigarettes and just toss them. —TIK ROOT

THINGS YOU CAN DO TO HELP

1. Properly discard cigarette butts.
2. Roll your own cigarettes, without filters.
3. Don't use e-cigarettes unless they can be recycled.

TAMPONS

PLASTIC PERVADES the most intimate aspects of modern life—including menstruation. Most American women will menstruate for about 40 years, bleeding for anywhere from two to 10 years in total. All that menstrual fluid has to go somewhere. For women in the United States, that somewhere usually ends up being a tampon or a pad, some 10,000 per woman. Most tampons come wrapped in plastic and encased in plastic applicators; many include a thin plastic fabric around the tampon itself. Pads contain even more plastic, from the leak-proof base to the synthetics that soak up fluid to the packaging.



It wasn't always so: Centuries-old records exist of prototampons constructed from natural materials such as rolls of grass, paper, cotton, or wool. The first commercially successful menstrual pads, branded as Kotex, went on the market in 1921. The Kimberly-Clark company made them with Cellucotton, an absorbent material made from wood pulp, which had been developed during World War I for medical bandages. About 15 years later the modern tampon became available, and for decades its design changed very little—until the plastics revolution arrived.

PLASTIC ADDED 1950s

"In the 1960s, material science is really booming and growing," says historian Sharra Vostral. "The chemists and manufacturers are really trying to figure out new applications for these superabsorbents they've devised."

Few women who use pads would want to return to the preplastic era. Tampons are another story. In Europe tampons may come wrapped in plastic and with polyester strings, but women generally don't use plastic applicators to insert them—whereas in the U.S., plastic applicators are popular. That's a good example of a general principle: A lot of our use of plastic is a culturally determined choice. It's not a technological imperative. — ALEJANDRA BORUNDA

THINGS YOU CAN DO TO HELP

1. Switch to menstrual cups or reusable pads.
2. Choose tampons without applicators or with cardboard ones.
3. Try out reusable menstrual underwear.

FOOD WRAP



The slick, transparent film we know as plastic wrap was originally a fluke of chemistry, a residue clinging stubbornly to the bottom of a flask in a 1930s laboratory. By the 1940s the material was used to make car seat covers and subway seats. Today consumers around the world, as well as stores, use water-resistant plastic wrap to protect food, and then the wrap is usually tossed in the trash after just one use.

Americans alone consume millions of rolls of plastic wrap each year. It's cheap and lightweight, and it keeps food fresh. That helps reduce food waste—a problem every bit as significant as plastic pollution.

The original discovery, made at a Dow Chemical Company lab, was polyvinylidene chloride, or PVDC, which was trademarked as Saran. Other wraps were made of polyvinyl chloride, or PVC. Those compounds create toxic byproducts when incinerated, so many companies have switched to wraps made of polyethylene.

PLASTIC ADDED 1930s

Recycling plastic wrap typically isn't cost-effective, and the wrap can be difficult to recycle. When it ends up in rivers and oceans, the wrap breaks down into microplastics, which pick up microbes and metal compounds. Then those contaminated bits of plastic harm the animals that mistake them for food.

— SARAH GIBBENS

THINGS YOU CAN DO TO HELP

1. Switch from plastic wrap to a reusable beeswax wrap.
2. Store leftovers in glass containers.
3. Avoid buying food wrapped in plastic.



3
TRILLION
cigarette butts are carelessly thrown away each year. Their filters are made of plastic, which makes them a key source of plastic pollution.



10
THOUSAND
tampons or pads are about what an American woman will throw away in a lifetime. Tampon applicators are usually plastic.





MILLIONS

of rolls of plastic food wrap are used by households in the U.S. every year. Typically used only once then discarded, plastic wrap can be difficult to recycle.


SOME ARE IN ROADSIDE ZOOS,
SOME ARE PETS. MANY ARE ABUSED.
CAPTIVE BIG CATS
IN THE U.S. OUTNUMBER TIGERS IN THE WILD,
PUTTING ANIMALS AND HUMANS
AT RISK.

The Tigers Next Door

BY **SHARON GUYNUP**
PHOTOGRAPHS BY **STEVE WINTER**





Bhagavan “Doc” Antle (far right) poses with his staff (left to right), Kody Antle, Moksha Bybee, and China York, in a pool used in his tiger show at Myrtle Beach Safari in South Carolina. Young cubs are a big part of the business; packages for playing and having photos taken with them run from $339 to $689 a person. At about 12 weeks old, cubs are considered too big and dangerous for tourists to pet.

PREVIOUS PHOTO

Clay, Daniel, and Enzo, three of 39 tigers rescued from an animal park in Oklahoma, gather at a pool at the Wild Animal Sanctuary in Keenesburg, Colorado. These cats will live out their lives here, with proper nutrition and vet care.


SAFARI'S
AMANDA
O-Ceda



Lori Ensign-Scroggins feeds chicken to Langley, her nearly 300-pound ti-liger (the offspring of a male tiger and a female cross between lion and tiger), in her kitchen in Broken Arrow, Oklahoma, as Amanda Badinger looks on. Langley was born nearly blind and with a limp, which can result from hybridization. He was adopted after he grew too big to pet.

We heard them before we saw them.



Tourists watch a tiger cub play with a stuffed toy during a petting and photo opportunity at Myrtle Beach Safari. Visitors may be unaware of the breeding practices necessary to create these cubs—or what happens to many captive tigers when they become too big to interact with the public and can't be used for breeding or display as adults.

Their squawks echoed from inside the neat, ranch-style home, sounding more like parrots than tiger cubs. Then James Garretson carried Hulk into the living room, where the McCabe family waited on the couch. The kids giggled as he placed the squirming cub on nine-year-old Ariel's lap and pushed a baby bottle into its mouth. "Hold the bottle, just like that. You got it?" She nodded.

Everyone beamed, fondling Hulk's rough, striped fur as Garretson hovered nearby. The 12-week-old, cocker spaniel-size cat clutched the bottle in his oversize paws, sucking with wild enthusiasm. When the bottle was empty, the cub wandered onto the coffee table and swatted our photo gear.

Garretson lured him back with another bottle



to give Ariel's five-year-old brother, James, a turn. Then the rambunctious cub leaped off the sofa, grabbed me from behind, gripped my legs with surprising strength, and tore five-inch scratches into my thighs. He sank his claws in and held on. Garretson peeled him off, and all made light of it with nervous laughs. Playful. Just acting like a kitten.

We met two more tiger cubs in a back room at the Ringling Animal Care Center in Oklahoma (which has no connection to the famous circus). Outside, we watched six adult tigers lounge in their pools or stalk one another, overweight but seemingly happy and living in clean enclosures.

That was in September 2018.

I later learned that seven tigers under Garretson's care at another facility had killed a woman in 2003. Court documents noted the cats were "extraordinarily hungry" and had reached through flimsy cattle fencing to rip Lynda Brackett's arm off "in a feeding-like frenzy." The 35-year-old, who worked there as a volunteer, bled to death. The U.S. Department of Agriculture (USDA) fined Garretson $32,560 and ordered him to never again exhibit, breed, buy, or sell animals that required U.S. federal licensing—including tigers. But by 2017 he was working at the Ringling center with new cats. The center was operating under a USDA license held by his girlfriend, Brittany Medina.

Four months after my visit, Garretson was

The nonprofit National Geographic Society, working to conserve Earth's resources, helped fund this article.

evicted from the property, which was leased in his name. A team from Turpentine Creek Wildlife Refuge drove from Arkansas to rescue the six adult tigers. One, named Diesel, was too ill to stand. He died four days later of a treatable bacterial blood infection thought to be carried by fleas and ticks, says veterinarian Kellyn Sweeley, who treated him. Hulk and the two other cubs had disappeared.

My visit to the Ringling center with photographer Steve Winter was just one stop during a two-year investigation into why there are likely more tigers living in cages in the U.S. than remain in the wild. We wanted to find out who owned them, what their living conditions are, how lax regulation has allowed them to proliferate, and how they're traded around the country.

Among other things, we found that most tigers in this country live in small zoos and animal attractions—known generally in the industry as "roadside" zoos—where care standards can vary widely, in some cases endangering the animals in them and the humans who visit them.

SMALL ATTRACTIONS

THAT OFFER VISITORS A CHANCE

TO PET TIGER CUBS FOR PHOTO OPS

FEED A CYCLE OF ABUSE

IN WHICH CUBS ARE DISCARDED

WHEN THEY'RE NO LONGER USEFUL.

TIGERS ARE IN CRISIS. At the turn of the 20th century, when Rudyard Kipling penned *The Jungle Book,* about 100,000 of the majestic cats roamed across Asia. They were wiped out by trophy hunts in India, the 1960s fashion craze for fur in the United States and Europe, the cats' shrinking habitat, conflicts with people, and poaching. Today perhaps 3,900 remain in the wild. Tigers hover closer to extinction than any other big cat.

After years of reporting on the illegal wildlife trade in Asia, I decided to look into tigers in America when I heard a talk by Carson Barylak, a policy specialist with the International Fund for Animal Welfare.

She said there may be 5,000 to 10,000 captive tigers in the United States. No one, including government officials, knows exactly how many there are, and there is no overarching federal law regulating big cat ownership.

Barylak showed a multicolored map illustrating a random patchwork of state laws. Some states ban private ownership. Others require a permit. Four have no statewide laws at all. In some places, it's easier to buy a tiger than to adopt a kitten from a local animal shelter.

You can get a USDA license to exhibit or breed gerbils—and then exhibit or breed any animal you want, including big cats. Entertainment drives the breeding and trading of tigers in the U.S., specifically attractions that allow customers to pet, feed, and pose with tiger cubs. Commercial breeders provide a constant supply of babies. Within some states, such commercial activities are legal if properly licensed by the USDA, which is tasked with enforcing minimum care standards for animals under the Animal Welfare Act. But we found mistreatment of animals and a range of illicit activities, including illegal wildlife trafficking, at many facilities we visited.

Tiger cubs are a gold mine, especially white ones. Tourists hug, bottle-feed, and snap pictures with adorable babies at roadside zoos, county fairs, and safari parks. A quick photo op or five-minute cuddle runs $10 to $100. A three-hour zoo tour with cub handling can run $700 a person. Guests often are told they're helping to save wild tigers. They leave happy and post selfies on social media.

What they don't know is the cubs' history or future. Most are born in tiger mills where females churn out two or three litters a year, compared with one litter every two years in the wild. Cubs are pulled from their mothers soon after birth, says Jennifer Conrad, a veterinarian with expertise in tigers. Many are poorly fed; unknown numbers die. Some are sold off before their eyes open.

When they're just a few weeks old, the cubs go to work, sometimes passed around for up to 10 hours a day. The profits can be enormous. (Tax records from Wildlife in Need, an Indiana roadside zoo run by Tim Stark, showed annual revenue of $1 million to $1.27 million in recent years. Stark, who still runs the facility but is under a court order not to allow cub petting, has been cited repeatedly by the USDA for violations related to sick or injured animals and was convicted of illegal wildlife trafficking in 2008.)

At three or four months, cubs reach what amounts to their expiration date: They're too big and dangerous to pet.

Some cubs become breeders or are put on display. Others simply disappear. Cub petting for photo opportunities "fuels a rapid and vicious cycle of breeding and dumping cubs after they outgrow their usefulness," said Representative Brian Fitzpatrick, a Republican from Pennsylvania. He and Mike Quigley, a Democrat from Illinois, co-sponsored the Big Cat Public Safety Act, a bill in the House of Representatives that aims to better protect animals and the public by prohibiting commercial breeding, public handling, and ownership of big cats as pets. The bill was introduced in the Senate recently by Richard Blumenthal, a Democrat from Connecticut.

There's evidence that some surplus tigers are killed to reduce inventory at roadside zoos and similar attractions. Dead tigers have been stuffed or sold off in parts: skins, teeth, claws, and skeletons. It's illegal to sell or ship them for purely commercial purposes across state lines under the Endangered Species Act.

Tentacles of this U.S. trafficking network have reached into Asia. In a recent case, a New York City man, Arongkron "Paul" Malasukum, was convicted of illegal wildlife trafficking for selling lion and tiger parts. As part of his plea, he admitted to shipping 68 packages of wildlife parts falsely labeled as ceramics and toys to Thailand. Court papers listed items seized from his home, including tiger skulls, teeth, and claws, as well as elephant tusks.

Captive-bred cats in Asia have fed a deadly commerce in tiger products for decades, stimulating demand that drives poaching, says Debbie Banks, a tiger trafficking expert with the U.K.-based Environmental Investigation Agency.

China is the largest consumer. Its market in tiger parts for luxury items and for use in traditional medicine drives this deadly trade. The country's tiger attractions, home to some 6,000 tigers, often double as "farms" that breed the animals to sell their parts.

WE WANTED TO SEE tigers in other situations, so we headed to Pennsylvania to meet Brunon Blaszak. He's a third-generation tiger trainer who tours with one of the country's few tiger acts. We watched him put his five tigers through traditional circus tricks in a rustic, portable enclosure at the Fayette County Fair. It was July, and brutally hot. During our two-plus days at the fair, the cats spent much of their time in five-by-eight-foot travel cages.



Joseph Maldonado-Passage, known as Joe Exotic, poses with Lightning, a four-month-old white cub, at G.W. Exotic Animal Park in Oklahoma. Once a prolific breeder and dealer of tigers and hybrids, he is in prison after being convicted in April on two counts of murder for hire and 17 federal wildlife charges—including killing five tigers.

We also met people who kept tigers as pets; some seemed to truly love them. One, Oklahoma exotic animal owner Lori Ensign-Scroggins, seemed oblivious to the potential danger of keeping such a large predator. She walked Langley, her nearly 300-pound ti-liger (a cross between a tiger and a lion-tiger mix), on a leash and sometimes took him into her home. She called him "Baby" and gave him special care, saying he'd been a cub-petting castoff. Langley had vision problems and walked with a rolling limp, problems most likely caused by hybridization.

In our travels we saw cats kept under conditions that ran the gamut. We saw cats pacing the perimeters of dirty, prison-like cages as well as calm cats in large, lush habitats. Some were beautiful and well cared for. Others bore

COLLECTION OF JOE EXOTIC





Director Pat Craig and Little Bit, his dog, make the rounds at the Refuge. One of the first arrivals, Budah, is settling into 35 acres of habitat, part of the 9,684-acre landscape. Together with the Wild Animal Sanctuary, the land creates the world's largest carnivore sanctuary.

A peek into the U.S. tiger trade

Tourism drives tiger breeding in the U.S., where many roadside zoos and other businesses charge guests to pet and pose with cubs. Some exhibitors and breeders make thousands of dollars a day from cubs that are sometimes as young as four weeks.

Tracking two networks

This map illustrates transfer records obtained from state wildlife agencies and watchdog organizations monitoring two of the largest facilities in the industry and their transactions with 48 other businesses. Records of all tiger trades are not available.

Trade networks

Serenity Springs

Records from 1996 to 2016 show this business (now closed) received 147 tigers and shipped out seven.

Greater Wynnewood

Records from 2010 to 2018 show this business shipped out 168 tigers and received 28.

Tiger transfers

1 ← Transferred into location

1 → Transferred out from location

1 ↔ Both in and out

Number shows total tigers transferred

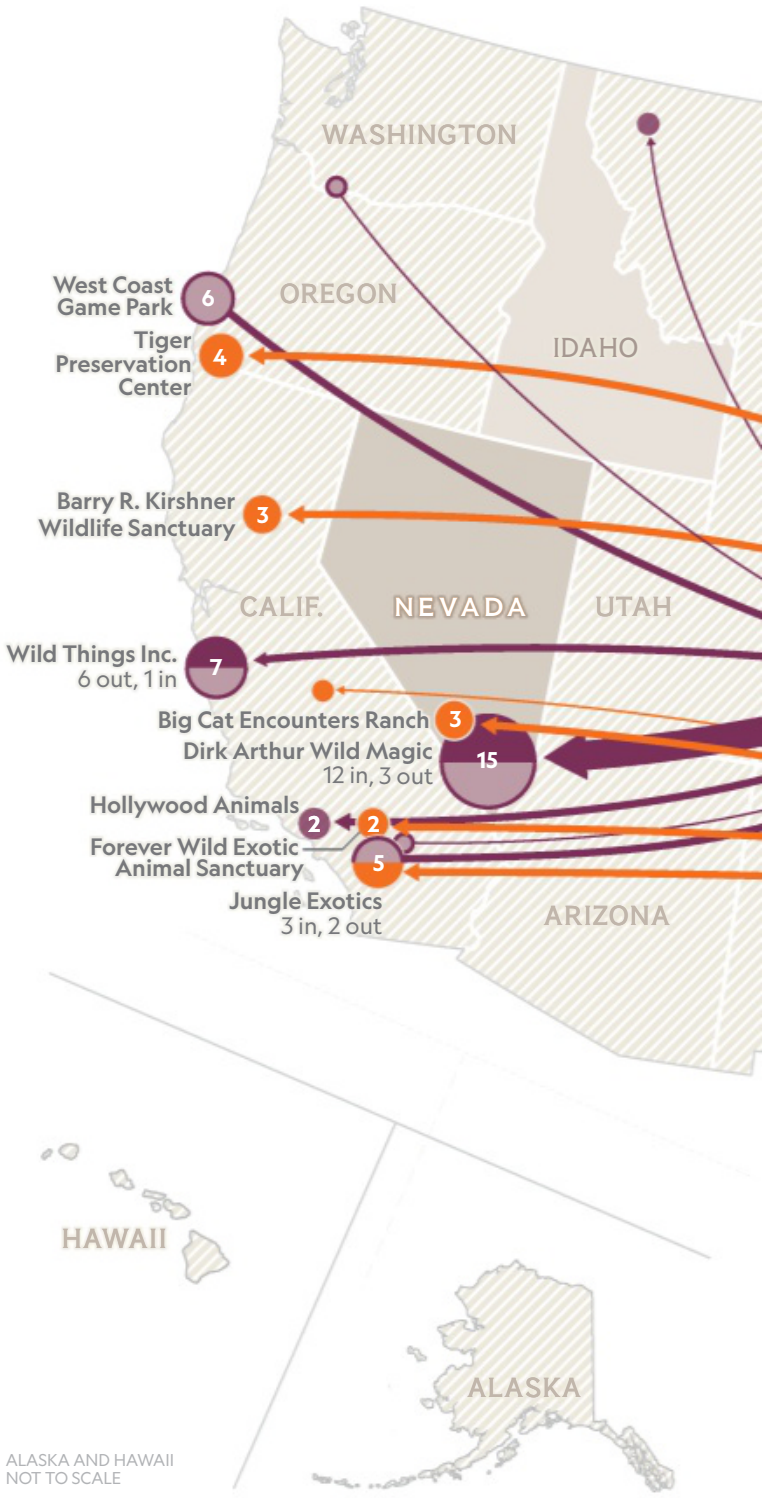
Number of transactions

1

2–7

8 or more

BEFORE 2016, GREATER WYNNEWOOD WAS CALLED EITHER G.W. EXOTIC ANIMAL PARK OR GAROLD WAYNE EXOTIC ANIMAL MEMORIAL PARK.



Proposed law for big cats

The Big Cat Public Safety Act, currently before Congress, would ban commercial breeding, public handling, and ownership of big cats as pets across the U.S.

State laws on keeping big cats as pets

No law (4 states)

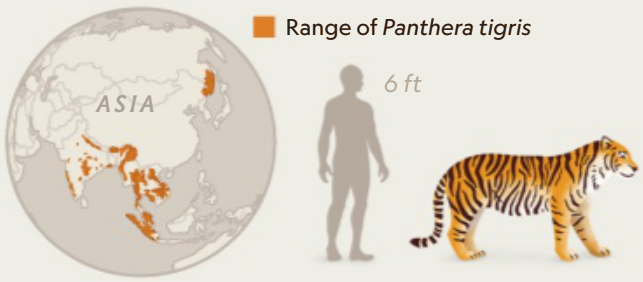
Permit required (10 states)

Ban (36 states and D.C.)

Despite state bans, it's still possible for breeders and exhibitors to obtain a license from the USDA to transfer and keep big cats.

Illegal to import

Tigers, native to Asia, were first brought to the U.S. in the early 1800s. Today the Endangered Species Act outlaws imports of tigers or tiger parts for commercial use. In China and Southeast Asia, tigers are farmed for meat, skin, and bones used in expensive tiger-bone wine and in traditional medicines.



RILEY D. CHAMPINE, TAYLOR MAGGIACOMO, NGM STAFF; SCOTT ELDER

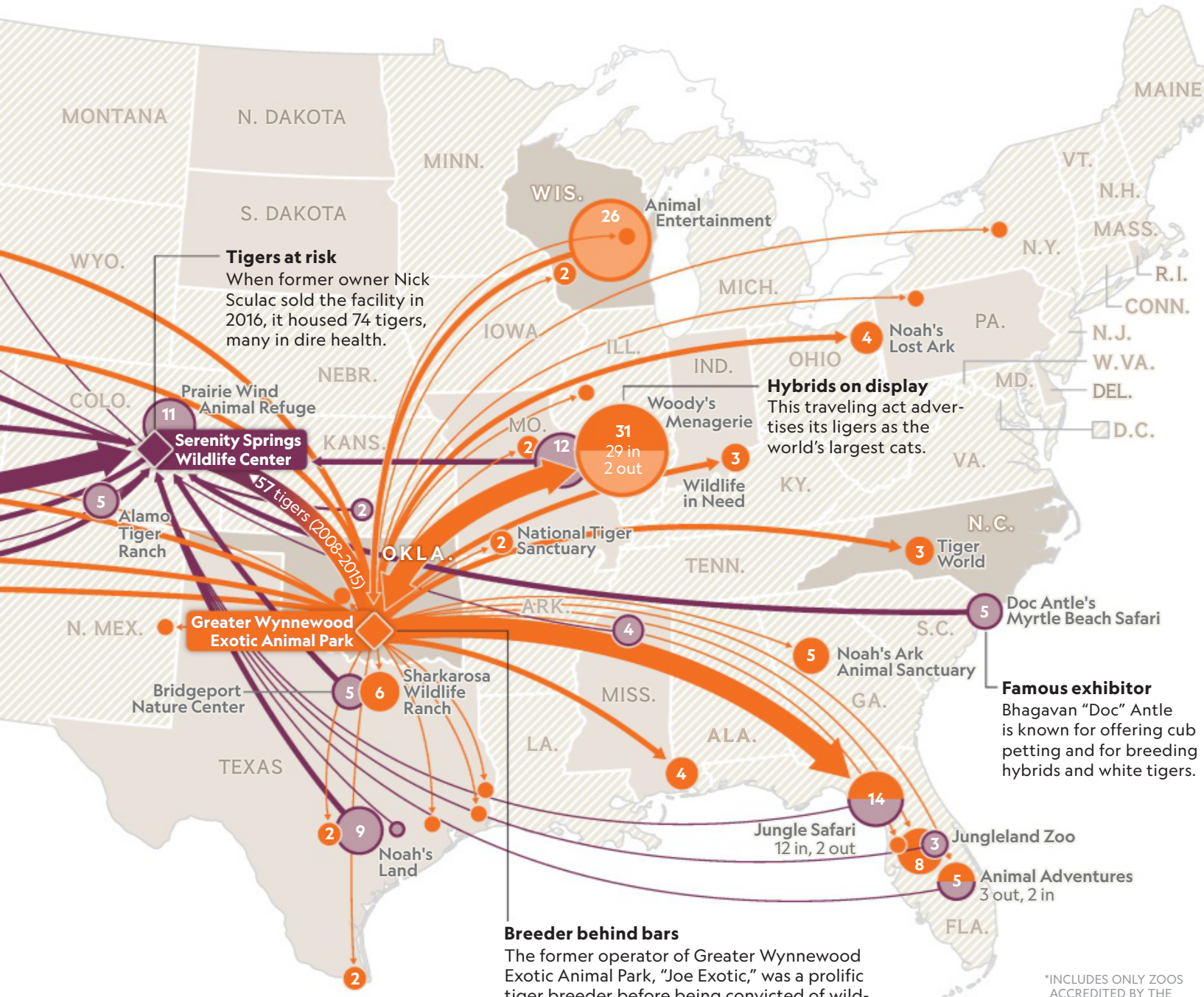
5,000
TIGERS IN THE U.S. (LOW ESTIMATE)

3,900
WILD TIGERS IN ASIA

1,659
TIGERS IN ZOOS* WORLDWIDE

More U.S. tigers than wild

It's unclear exactly how many captive tigers are in the U.S., as there is no official count; estimates range from 5,000 to 10,000. Most of them are kept in roadside zoos or as pets.



*INCLUDES ONLY ZOOS ACCREDITED BY THE ASSOCIATION OF ZOOS AND AQUARIUMS OR A REGIONAL EQUIVALENT

Unnatural creation

Some roadside zoos breed tigers with lions to draw tourists. These hybrid felines don't exist in the wild and have no conservation value. They often suffer from health problems, including neurological issues and obesity.



Liger
Ligers grow much larger than a lion or tiger. Standing on their hind legs, they can measure up to 11 feet tall and weigh more than 1,000 pounds.

SOURCES: OKLAHOMA DEPARTMENT OF AGRICULTURE, FOOD, AND FORESTRY; COLORADO PARKS & WILDLIFE; TURPENTINE CREEK WILDLIFE REFUGE; HUMANE SOCIETY OF THE UNITED STATES; CARNEY ANNE NASSER, MICHIGAN STATE UNIVERSITY COLLEGE OF LAW; ASSOCIATION OF ZOOS AND AQUARIUMS; PETA; SPECIES360; IUCN; PANTHERA; WWF



Dozer paces in his enclosure after getting a treat at Catty Shack Ranch Wildlife Sanctuary in Jacksonville, Florida, an attraction that rescues big cats and other exotic animals. The nonprofit facility has 22 tigers and offers tours but doesn't allow hands-on contact and says it doesn't breed, trade, or sell animals.



scars, were skinny or fat, were listless or covered in open sores. Some displayed symptoms of inbreeding or poor nutrition and were crippled, cross-eyed, or deformed. None seemed to be the confident, wide-ranging predator that *Panthera tigris* evolved to be.

Highly regarded zoos, aquariums, and animal parks—236 facilities—are accredited by the Association of Zoos and Aquariums (AZA), which does not allow public contact with tigers. The AZA—whose members include facilities owned by The Walt Disney Company, the parent company of National Geographic Partners—also allows only purebred tigers to be bred, and only for conservation purposes. Wildlife specialists say that such policies reflect some of the improvements in the care of exotic animals that have unfolded over the past three decades, as saving species and showing animals in more natural habitats have become priorities.

SOME OF THE TIGERS

WE SAW LOOKED BEAUTIFUL

AND WELL CARED FOR.

OTHERS BORE SCARS,

APPEARED TOO SKINNY OR FAT,

OR WERE LISTLESS OR COVERED IN SORES.

Attractions that breed tigers for commercial purposes, allow cub petting, or both—including some of the roadside zoos and parks we visited—often are not accredited by any organization that sets specific guidelines for exotic animals. Some belong to the Zoological Association of America (ZAA), a trade association that allows cub petting.

MANY ROADSIDE ZOOS brand themselves as sanctuaries, but few meet the criteria for them, says Bobbi Brink, director of Lions Tigers & Bears, an exotic animal rescue and sanctuary in San Diego. These standards, she says, include no breeding, buying, or selling of animals; prohibiting the public from hands-on contact with them; and providing proper nutrition, care, and a lifetime home.

Facilities that exhibit, breed, or deal in captive exotic "warm-blooded animals not raised for food or fiber" must have a USDA license. Some captive-wildlife experts, including Cathy Liss, president of the nonprofit Animal Welfare Institute (AWI), say that recently the USDA hasn't done enough to ensure animals' safety. Liss questions why the department has gutted enforcement of the Animal Welfare Act, noting that the law's care and safety rules "are so modest that if you can't meet them, you shouldn't be in business."

From 2016 to 2018, new investigations into captive-animal welfare and safety issues dropped by 92 percent, from 239 to just 19. The department also wrote far fewer citations, issuing 1,716 in 2018, compared with 4,944 two years before—a 65 percent drop, according to AWI.

In June the U.S. House of Representatives reprimanded the USDA for substituting "teachable moment" conversations for active enforcement, noting concern over "how the Animal Care program is being managed." It ordered the USDA to "immediately require all its inspectors to cite every observed violation at any visit to a regulated entity."

Congress told the USDA to reinstate information that had been scrubbed from its website in 2017, which had made it impossible to monitor problem facilities for neglect, abuse, or safety issues that endanger animals and the public. The department later restored some information, but the reports are heavily redacted. I asked the USDA about this and other issues: Problems counting and tracking tigers; the welfare of cubs that are handled by the public; why venues with decades of serious violations are still licensed; and more. After repeated requests for an interview and a series of email exchanges, the USDA provided a written reply that broadly quoted regulations and offered web links, but gave few specifics. The department refused my request for an interview and declined to make someone available to address questions.

THE NEXT TIME I saw James Garretson, he was on the witness stand in a federal court in Oklahoma City.

It was March 2019, and he was testifying against "Joe Exotic," a man who owned what prosecutor Amanda Green said was "quite possibly the largest population of big cats in captivity in the U.S."

His real name is Joseph Maldonado-Passage,

and he'd been indicted on 19 wildlife charges and two counts of murder for hire. Garretson had known him for decades and bought cats from him. He'd taped their conversations and collected text messages that became key evidence in a trial that revealed widespread criminal activity in the U.S. tiger industry.

This was the first time I'd seen Joe Exotic, though I felt like I knew him. I'd followed five of his Facebook pages for more than a year. I'd seen many online videos, interviews, and episodes of *Joe Exotic TV*, the low-budget online reality show he streamed from his parents' Oklahoma zoo, G.W. Exotic Animal Park, which opened in 1999. At one time, he claimed to own 227 tigers.

Joe Exotic is a showman who loves to talk and craves the spotlight. At 56, he sports a signature horseshoe mustache and dyed-blond mullet. He's inked in tattoos depicting tigers, past lovers, and bullet holes dripping blood.

He once ran cub-petting photo sessions in shopping malls, parking lots, and county fairs across the West and Midwest. He staged rudimentary magic shows with tigers as "the Tiger King," dressed as an open-shirted, Las Vegas–style entertainer. He ran for president in 2016, garnering 962 votes, and for Oklahoma governor in 2018, when he got 664.

Back home, Joe Exotic was a prolific tiger breeder and dealer. Prosecutors said he falsified tiger birth records that he showed to USDA inspectors to hide the birth and sale of cubs.

Joe Exotic's house was a tiger day care center, said his niece, Chealsi Putman, who worked at the zoo. The living room was sometimes crammed with six or seven playpens for litters of cubs.

He bred white tigers, which often are inbred. They were among the most popular, drawing huge crowds to the zoo. He took greatest pride in breeding tigers with lions, "chimera" hybrids that don't exist in nature: ligers (lion dad, tiger mom), tigons (the reverse)—and then li-ligers, ti-ligers, and more.

His troubles began soon after the zoo opened two decades ago. The USDA cited him repeatedly for violations of Animal Welfare Act standards: Inspectors documented sick, injured, mistreated animals and unclean, unsafe enclosures contaminated by vermin. The agency fined him $25,000 in 2006. Major problems continued: an escaped tiger, a mauled employee, at least 22 cubs that died over an eight- to 10-month period.

Then in 2011 came protests over his mall shows, sparked by Carole Baskin, founder of Big Cat Rescue sanctuary in Florida. She'd launched 911 Animal Abuse, a website that exposes mistreatment of big cats and opposes separating cubs from their mothers to use the babies as photo props.

Mall chains stopped hiring Joe Exotic. He threatened Baskin on social media and sparked hate fests on Facebook against her and others he called "animal rights terrorists." He retaliated by renaming his road show Big Cat Rescue Entertainment, even copying the sanctuary's logo. Baskin then sued over intellectual property rights and won a million dollars in settlements in 2013. It financially devastated Joe Exotic, who took on a business partner to help pay the bills.

Joe Exotic told anyone who'd listen that he wanted Baskin dead. In a YouTube video, he said, "Carole Baskin better never, ever, ever see me face-to-face, ever, ever, ever again." Then he blew the head off an effigy of her with a revolver.

The conflict grew more serious in 2016, Garretson testified, when Joe Exotic "asked if I knew somebody that would kill" Baskin and said he'd offer $10,000 to anyone who would agree to do it.

Some months later, Garretson said, Joe Exotic mentioned that he'd shot some of his own tigers. Garretson decided that was enough. He'd been contacted by Matt Bryant, a special agent at the U.S. Fish and Wildlife Service, and he signed on as a government informant. Court documents say Garretson collected tapes and texts as Joe Exotic hired an employee, Allen Glover, to kill Baskin and then sold a cub to pay for a $3,000 deposit on the hit.

When Glover disappeared with the money, Joe Exotic tried again. This time, the would-be hit man was an undercover FBI agent.

Joe Exotic was arrested on two counts of murder for hire in September 2018. Federal wildlife charges were added later; those included illegally selling and transporting endangered species across state lines, falsely labeling those sales as "donations," and killing five tigers.

IN COURT, Glover's testimony raised shivers. He testified that he'd told Joe Exotic that he would cut off Baskin's head with a knife. (Glover was never charged.)

Baskin wasn't physically harmed, but tigers were. Under oath, former zoo employees Dylan West and Eric Cowie described what happened in October 2017. After tranquilizing five tigers, Joe Exotic "walked up to them with



Tiger trainer Brunon Blaszak puts cats through circus tricks at one of his three daily shows at Ohio's Crawford County Fair. Tigers seen there over a three-day period were held in small travel cages when not performing. There's growing backlash against such shows; critics say the acts are inhumane.


18 FLAVORS OF POP



Staff members at Myrtle Beach Safari try to position two tigers, probably hybrids, for a photo session with a shirtless Kody Antle, the owner's son. He provides much of the venue's social media presence, posing in photos and videos. He has more than a million Instagram followers.



the .410 [shotgun] and put it against their head[s] and pulled the trigger," West said. Cowie testified that the victims, named Samson, Delilah, Lauren, Trinity, and Cuddles, were "dispensable" because they weren't producing cubs.

Special Agent James Markley described what Fish and Wildlife investigators unearthed a year later. Digging down five feet, "we found five tigers lined up, side by side, like hot dogs in a pack."

In April the jury convicted Joe Exotic on 17 wildlife charges (two were dropped) and the murder-for-hire counts, both felonies. He faces up to 69 years in prison.

Under the Endangered Species Act, killing tigers is a misdemeanor. Joe Exotic insisted that the law was written to apply to wild animals, not those born in a zoo. In a recent email, he said he had a right to "euthanize my own property."

Environmental crimes prosecutor John Webb characterized it differently. "It was tiger execution," he said. It wasn't the first.

In 2003 Illinois corrections officer William Kapp was convicted for his role in shooting 18 tigers and leopards in their cages and brokering the sale of their meat and skins to buyers. The same year, California Department of Fish and Wildlife investigators found 90-some dead animals—mostly tigers, including 58 cubs—in a freezer when they raided the home of John Weinhart, owner of Tiger Rescue, a facility in Colton, California, that billed itself as a sanctuary for animals that had worked in the entertainment industry.



Brittany Medina watches 12-week-old Hulk jump around her living room while waiting for the next cub-petting clients at Ringling Animal Care Center in Oklahoma in 2018. When the operation closed last January, six adult tigers were rescued by Turpentine Creek Wildlife Refuge.

In emails from jail, Joe Exotic questioned why other breeders have not been charged, alleging that they have sold, illegally transported, or killed big cats—and continue to.

So, he asked, "why am I the only one in jail?"

THE UNITED STATES has been a leader in the fight against the illegal wildlife trade, a business involving international crime syndicates that analysts say could amount to as much as $20 billion a year. In 2015 the U.S. and China negotiated a near-total bilateral ban on ivory sales.

But the U.S. has less credibility when it comes to protecting tigers because of its large, poorly regulated population of captive tigers. Breeding these animals for "trade in parts and derivatives" was outlawed in a 2007 decision by the Convention on International Trade in Endangered Species (CITES), a treaty signed by 183 members worldwide, including the United States. Now CITES is investigating seven nations linked to possible trafficking of captive-bred tigers: the U.S., China, Vietnam, Laos, Thailand, the Czech Republic, and South Africa.

Fish and Wildlife special agent Phillip Land told me that "exporting wildlife out of the United States is becoming more prevalent." A State Department email to congressional staff last year noted that private ownership of tigers in the U.S. is "inconsistent with our stance against tiger farming and trafficking."

One U.S. official told me he was laughed at by Chinese delegates at a CITES meeting when he raised a question about China's tiger farms. He said one of the delegates told him, "At least we know how many tigers we have."

PHILIP NYHUS, a professor at Maine's Colby College, traces the massive striped cat's arrival in the United States to the early 1800s. Crowds flocked to see exotic animals from far-flung lands in traveling menageries.

By 1833 animal trainer Isaac van Amburgh was using tigers in his act, climbing into their cages dressed as a gladiator. He was criticized for his brutality; he was said to have beaten his tigers with a crowbar. Such dominance training helped embed a notion in the American psyche, Nyhus says, that these dangerous beasts must be subdued by macho trainers.

When the nation's first zoo opened in





Illusionist Jay Owenhouse walks Selah at his home in Bozeman, Montana. She is one of three tigers he uses in his touring magic act. Exhibitors like Owenhouse must hold a USDA license.



Philadelphia in 1874, it exhibited a tiger, as did many of the hundred-plus "zoological parks" and 650 circuses that sprouted nationwide during the next half century.

Fast-forward to 1960. Billionaire John Kluge bought a white Bengal tiger, Mohini, from India's maharaja of Rewa and donated it to the National Zoo in Washington, D.C. The female had ice-blue eyes, a pink nose, and milky fur slashed by dark stripes. She was one of only seven in the world, all in captivity.

Mohini wasn't an albino or a separate subspecies. Her snowy coat came from a pair of recessive genes, one from each parent. Breeding with her half brother produced the first white cub in the U.S. in 1964. The Cincinnati Zoo borrowed two of her children, which also were bred to one another. This was the start of a practice that eventually produced 91 white cubs from 1974 to 1990. The *Cincinnati Enquirer* reported that the zoo sold the cubs for $40,000 to $60,000 each.

The Cincinnati Zoo, which is accredited by the AZA, stopped breeding white tigers after 1990. In 2012 the AZA banned the practice for its affiliates. Both did so because of numerous health problems in inbred cats and because breeding for white tigers had no conservation value.

"The days of breeding white tigers in accredited zoos are over," says Thane Maynard, director of the Cincinnati Zoo. AZA president Dan Ashe, director of the Fish and Wildlife Service from 2011 to 2017, says breeding for recessive traits "is simply unethical from the standpoint of the welfare of the population and of the individual animal."



Terry's Taxidermy stuffed and displayed these two tigers. The owner, Terry Mayberry, says he acquired them from an Oklahoma animal park. Because both businesses are in the same state—and the animals were not transported across state lines—this exchange was not prohibited by the Endangered Species Act.

Descendants of the early white tigers began appearing in attractions across the U.S.: Siegfried Fischbacher and Uwe Ludwig Horn bought seven whites from Cincinnati and began putting them in their "Siegfried & Roy" magic show, which dazzled Las Vegas audiences for decades and grossed up to $45 million a year. The spectacle included Roy dancing with a 400-pound cat. The show ended in 2003 when a tiger mauled him onstage.

By then America had fallen in love with tigers, and they were everywhere. In 1998 Fish and Wildlife limited its captive-wildlife registration requirements to purebreds. That meant anyone could buy, breed, and sell "mutt" Bengal-Siberian or other generic mixes across state lines without a permit. It "incentivized mass breeding," says Carney Anne Nasser, a captive-tiger expert and professor at Michigan State University.

You could pet a cub at a flea market, a county fair, a mall. Tigers lived in people's homes, garages, and flimsy cages in backyards.

But when those adorable cubs grew, they tore up the furniture and attacked the kids. Many owners couldn't handle a dangerous 300- to 450-pound carnivore or the $10,000-a-year food and vet bills that came with it. The first havens for these cast-off big cats are still open today: Baskin's Big Cat Rescue in Florida, Pat Craig's Wild Animal Sanctuary in Colorado, and Scott and Tanya Smith's Turpentine Creek Wildlife Refuge in Arkansas. All are accredited by the Global Federation of Animal Sanctuaries. Craig is building a facility that will allow cats to roam in 35- to 500-acre habitats.

IN FEBRUARY 2017 we followed the Smiths on a caravan-style drive from Colorado to California. Four tigers were in the trailer they pulled behind them, the last of 74 from Serenity Springs Wildlife Center in Calhan, Colorado. They were relocated to 15 sanctuaries in a six-month marathon—the largest tiger rescue in U.S. history. The former owner, Nick Sculac, had sold Serenity Springs, citing health problems. Records left behind in his office revealed that he'd been among America's biggest tiger breeders. The USDA had filed complaints against him in 2012 and 2015, detailing animal abuse, neglect, and safety violations. He lost his exhibitor's license in April 2017, eight months after he sold the facility.

The Smiths said the conditions at Serenity

Springs were "a horror show." The air was black with flies attracted by rotting garbage. Dead birds floated in animal pools. Enclosures were shin-deep in excrement. One tiger was missing a leg, possibly from fighting with a cage mate. Another had a softball-size tumor under its chin. Many had broken, abscessed teeth and limped from declawing; their claws had been removed by amputating the first joint of their toes.

Three four-month-old white cubs, Blackfire, Rocklyn, and Peyton, were in critical condition. They could barely drag themselves to their water bowls and cried when they moved. They were rushed to the Smiths' Turpentine Creek sanctuary for emergency care. X-rays showed each had a malformed pelvis and misshapen, nearly transparent bones so riddled with fractures they resembled a mosaic. Pulled from their mother and poorly nourished, they'd developed metabolic bone disease, says Emily McCormack, the sanctuary's animal curator. "Every day we asked each other, 'Can we save them?' "

TIGERS LIVED IN HOMES,

GARAGES, AND FLIMSY CAGES

IN BACKYARDS. BUT WHEN

THOSE ADORABLE CUBS GREW,

THEY TORE UP THE FURNITURE

AND ATTACKED THE KIDS.

We traveled to Arkansas in September 2018 to see what had become of the cubs. Blackfire, the male, sauntered to the fence, chuffing a tiger hello. At two years old, he was magnificent. He and his sisters still limped, and McCormack said they're on daily pain medication, but they chased and pounced like kittens in their large, grassy enclosure.

TIGERS ARE EXTREMELY dangerous and cannot be domesticated, says Tim Harrison, a retired police officer with expertise in exotic animals and public safety. A lot can go wrong with tigers in captivity, he says, if a hurricane or tornado hits, a fire breaks out, or humans simply make a mistake. Eight years ago, an incident in Zanesville, Ohio, showed what can happen when someone who keeps wild predators. Exotic pet owner Terry Thompson apparently set 56 of his animals loose—including 38 big cats—then shot himself. Muskingum County sheriff Matthew Lutz and his deputies had to kill most of the animals to protect the community.

Edmund Kelso, Jr., a former FBI bomb expert, expressed his concern in a letter to Congress: "If I had a choice of working on an IED or responding to an emergency involving a dangerous big cat, I would definitely select the former. This should underscore how dangerous it truly is for these animals to be left in untrained hands in back yards and roadside zoos."

There's a long list of tragic stories involving people who have lost limbs or been bitten, mauled, or killed. Among them: Haley R. Hilderbrand, 17, who was killed while posing for her senior pictures with a male tiger in Kansas in 2005; and a three-year-old boy who was blinded by his father's tiger in North Carolina in 1995.

The number of attacks is unknown: No government agency keeps records of them, and injuries often go unreported. Eight former roadside zoo employees who'd been bitten or clawed told me they'd been discouraged from seeing a doctor so no one would find out. They also said they'd received little or no training in handling big cats. In 2012, seven nonprofits petitioned the USDA to ban public contact with dangerous wildlife at its licensed facilities, citing a "welfare and public safety crisis." By law, the department must respond. But seven years later, it has "no projected date" for doing so, the USDA said in a written statement.

I SPENT TWO DAYS at Myrtle Beach Safari, a wildlife attraction in South Carolina.

Bhagavan "Doc" Antle, the owner, is known for producing white tigers. The park promotes itself on Instagram, where Antle's son Kody posts pictures of himself shirtless, with his father's animals and videos of their animals' antics. He has more than a million followers.

In May I joined 79 people on a three-hour "wild encounters" tour. It began in a safari lodge–style living room. TVs played loops of Doc Antle's appearances on *The Tonight Show With Jay Leno,* as well as films and shows he's

trained animals for. (National Geographic has worked with Antle in the past but has decided it will no longer do so.)

The tour was highly scripted. Attractive young women emceed, peppering their circus-style oratory with puns. After a lively intro, staffer Robert Johnson outlined conservation programs funded by Antle's nonprofit, the Rare Species Fund (RSF). "You guys are part of it now. Congratulations!" he said.

He pointed to the windows behind the crowd. Outside, Kody walked a monstrous, 900-pound liger named Hercules on a chain, a tawny, lionish hybrid cat with faint stripes and a massive head. All took turns posing for photos in front of him. We walked through a manicured jungle setting to a large gazebo. Inside, guests played with tiger cubs as photographers snapped pictures. Everyone was smitten. Back in the lodge, visitors gushed as they waited for pictures. No cameras were allowed, so most bought a photo package. One visitor booked a swim-with-a-tiger session for $5,000. After dark, nearly 30 joined a "night safari." I estimated the day's receipts at about $50,000.

The tour gave customers the impression that it was all for conservation. The RSF supports some conservation projects, but staff wouldn't say how much the fund donates each year, and some of its activities have raised questions. Among them are "educational" tiger performances at Renaissance fairs, where Antle told me he'd sold about a million photo ops with adult tigers and ligers. Antle also has delivered tigers to Thailand's Samut Prakarn Crocodile Farm and Zoo; in June *National Geographic* published a story about animal abuse at that attraction.

The fund's website says it is "working to improve wildlife legislation." In the past decade, Antle's businesses have spent at least $1.15 million lobbying on proposed regulations on captive wildlife and big cat issues—including $60,000 to lobby against the Big Cat Public Safety Act.

The future of tigers in the U.S. remains to be seen. But this much is clear: As long as tourists seek to cuddle tiger cubs and be dazzled by hybrid cats—and as long as U.S. policies make owning dangerous cats so easy—the formula for abuse will remain in place. ▯

Sharon Guynup is a National Geographic explorer and a global fellow at the Wilson Center. She focuses on wildlife and trafficking. Photographer **Steve Winter** specializes in big cats.

Some guidelines for seeing wild animals

Figuring out how to observe exotic animals humanely can be complicated and confusing. Watching them from a safe distance in the wild is ideal, animal welfare advocates say. To assess how facilities treat captive animals, you can refer to internationally recognized standards inspired by a 1965 U.K. government report. Known as the "five freedoms," they're used by animal welfare groups worldwide and by the U.S., Canadian, and European veterinary medical associations.

1 Freedom from hunger and thirst
Look for facilities where animals appear to be well-fed and have access to clean water at all times.

2 Freedom from discomfort
Observe whether animals have an appropriate environment, including shelter, ample space, a comfortable resting area, and a secluded place away from crowds.

3 Freedom from pain, injury, or disease
Avoid facilities where animals are visibly injured or are forced to participate in activities that could injure them or cause them pain—or where enclosures aren't clean.

4 Freedom to express normal behavior
Being chained, performing, and interacting with tourists—giving rides, posing with them, being washed by them—are not normal for a wild animal, even one born in captivity.

5 Freedom from fear and distress
Be aware that fear-based training, separation of babies from mothers at birth, unnatural noises, and large crowds cause distress.

To read more reporting about wildlife, visit *natgeo.com/wildlife-watch*.

Ennedi Reserve

CHAD

Deep in the northeastern Sahara, the severe sandstone towers of the Ennedi plateau shield water holes, oasis vegetation, beleaguered wildlife, and ancient petroglyphs on canyon walls. The conservation group African Parks (AP) has assumed management of the Ennedi Natural and Cultural Reserve in a partnership with the Chadian government.

By **DAVID QUAMMEN**
Photographs by **BRENT STIRTON**

SAVING AFRICA'S PARKS

TO RESCUE THE CONTINENT'S ICONIC WILDLIFE FROM POACHING AND OTHER HUMAN THREATS, ONE CONSERVATION GROUP IS TREATING DEGRADED PARKS AS IF THEY WERE FAILING BUSINESSES IN NEED OF NEW MANAGEMENT. IT'S WORKING.



LAST WILD PLACES

African Parks is a conservation partner of the National Geographic Society's Last Wild Places initiative.

Garamba National Park

DEMOCRATIC REPUBLIC OF THE CONGO

In a war-wracked region, Garamba attracts rebels keen to poach elephants because tusks can pay for munitions. A ranger—part of a force trained and equipped by AP—stands guard over recovered tusks.

The headquarters at Zakouma National Park, in southeastern Chad, is a sand-colored structure with a crenellated parapet that gives it the look of an old desert fortress. Outside the door to the central control room on the second floor hangs an image of a Kalashnikov rifle, circled in red, with a slash: No weapons allowed inside. Kalashnikovs are ubiquitous in Zakouma. All the rangers carry them. So do the intruders who come to kill wildlife.

Acacias shade the compound, Land Cruisers arrive and depart, and not many steps away, several elephants drink from a pool. Although the animals seem relaxed here, so close to the headquarters hubbub, they aren't tame; they are wary but thirsty. Zakouma, a national park since 1963, has at times been a war zone for elephants. Fifty years ago, Chad as a whole may have had as many as 300,000, but from the mid-1980s that number declined catastrophically due to





Zakouma National Park

CHAD

This park, a region of grasses and acacia in southeastern Chad, lost more than 90 percent of its elephants during the century's first decade, mostly to mounted bandits (janjaweed) from Sudan. AP took over management in 2010, and now the elephants feel safe enough to disperse more broadly and produce an abundance of calves.



Zakouma National Park

CHAD

Fire-and-move exercises with live ammunition are part of ranger training at Zakouma, as they are at Garamba in the Democratic Republic of the Congo (DRC) and in other areas managed by African Parks. CEO Peter Fearnhead denies that AP is “a highly militarized organization,” but says there “absolutely” is rigorous law enforcement.



wholesale slaughter by well-armed poachers, until Zakouma became an uneasy refuge for the largest remnant, about 4,000 elephants.

Then, during the first decade of this century, more than 90 percent of Zakouma's elephant population was butchered, mostly by Sudanese horsemen riding in from the east on paramilitary raids for ivory. (See "Ivory Wars: Last Stand in Zakouma," *National Geographic*, March 2007.) These raiders are known as janjaweed, an Arabic word loosely translated as "devils on horseback," though some ride camels. Their origins lie among nomadic Arab groups, highly skilled equestrians, who, once armed and supported by the Sudanese government, became ruthless strike forces during the conflict in Darfur and, later, freelance bandits lusting after ivory. For a while it seemed they might kill every elephant in Chad.

Then in 2010, at the invitation of the Chadian government, a private organization called African Parks (AP) took over management of Zakouma, and the trend came to a sudden stop. Founded in 2000 by a small group of conservationists concerned with such hemorrhagic losses of the continent's wildlife, the nonprofit AP contracts with governments to restore and run national parks—with the stipulation that it will exercise full control on the ground. AP presently manages 15 parks in nine countries, bringing outside funding, efficient business practices, and rigorous law enforcement to some of Africa's most troubled wild landscapes.

At Zakouma, law enforcement involves more than a hundred well-trained and well-armed rangers, mostly men but also women, deployed through a coordinated and strategically sophisticated operation. Leon Lamprecht, a South African who grew up in Kruger National Park, where his father was a ranger, is AP's park manager of Zakouma.

"We are not a military organization," Lamprecht said, while showing me a trove of weapons and ammunition in the armory, a locked shed on the ground floor of headquarters. "We are a conservation organization that trains our rangers for paramilitary."

Peter Fearnhead, the CEO of African Parks and one of its co-founders, bridled at the notion that the organization is highly militarized. But he still stressed, when we spoke by phone, the need for well-armed security in the parks—not just for the protection of wildlife but also for people in nearby communities who may be subjected to rape, pillage, and plunder by the next wave of demons on horseback. "They recognize that it's the park that brings stability, safety, and security for them," Fearnhead said.

Lamprecht drew me a pyramid diagram of the levels of tasks as AP sees them. You build the base of the pyramid with law enforcement, infrastructure, solid staff—"area integrity." After that you can advance upward: community development for local people, tourism, and ecological research.

THE NERVE CENTER of this effort is the central control room, where fresh intelligence on elephant locations and any troubling human activity—an illegal fishing camp, a gunshot, a hundred armed horsemen galloping toward the park—is used to determine ranger deployments. The sources of information include reconnaissance overflights, foot patrols, GPS collars on elephants, and handheld radios placed with trusted informants in villages around the park.

The daily briefing begins at 6 a.m. There's a long desk with a pair of computer monitors and, on the wall, a large map decorated with stickpins. On the morning of my visit, Tadio Hadj-Baguila, an imposing Chadian man in a turban and camo fatigues, head of law enforcement for the park, presided in French.

Lamprecht explained to me that the black pins on the map represent elephants. The green pins are regular ranger patrols—known as Mamba teams—six rangers to a team, bushwhacking through the park on five-day rotations. Their movement is dictated by the elephants, which the Mambas follow discreetly, like guardian angels.

And this, said Lamprecht—pointing to a red-and-white pin set aside from the map—represents a Phantom team, two rangers, doing long-range reconnaissance. Those are so secretive that not even the radio operator knows their locations, only Lamprecht and Hadj-Baguila.

The data are collated each morning and afternoon. "We play chess twice a day," Lamprecht said. Across the chessboard are janjaweed and every other sort of poacher who might test the boundaries of Zakouma.

High on the wall, above the maps, hangs a series of plaques commemorating the losses, low

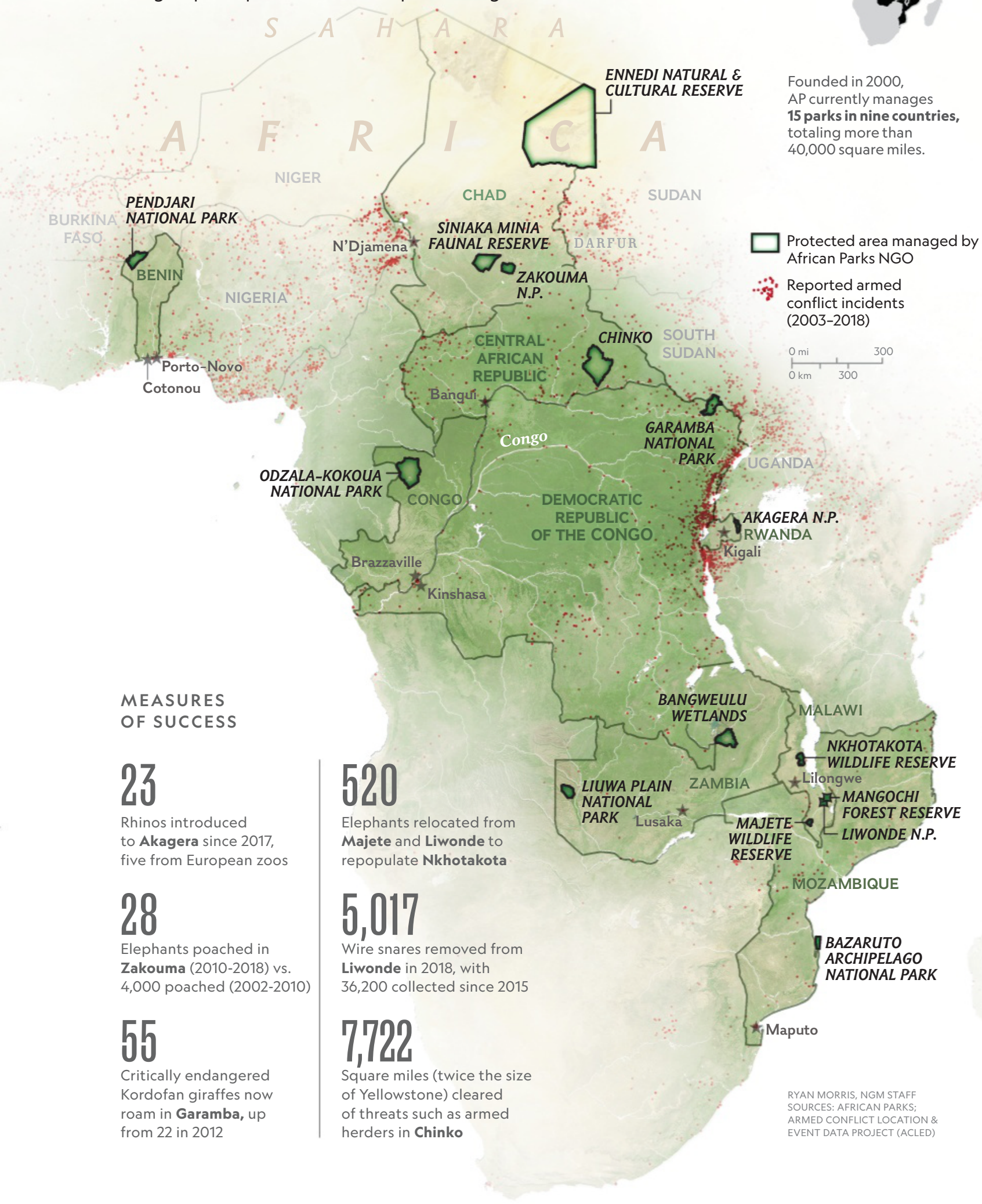
This article is supported by the Wyss Campaign for Nature, which is working with the National Geographic Society and others across the globe to help protect 30 percent of our planet by 2030.

A NOVEL ALLIANCE

The conservation group African Parks (AP) has a new approach to rescuing Africa's wild spaces as armed conflict, poaching, and other threats encroach. It agrees to provide all the resources to rehabilitate a park, restore its wildlife, and support surrounding communities—but the government, which remains the owner of the park, must give the group complete control over park management.



Founded in 2000, AP currently manages **15 parks in nine countries,** totaling more than 40,000 square miles.



MEASURES OF SUCCESS

23
Rhinos introduced to **Akagera** since 2017, five from European zoos

28
Elephants poached in **Zakouma** (2010-2018) vs. 4,000 poached (2002-2010)

55
Critically endangered Kordofan giraffes now roam in **Garamba,** up from 22 in 2012

520
Elephants relocated from **Majete** and **Liwonde** to repopulate **Nkhotakota**

5,017
Wire snares removed from **Liwonde** in 2018, with 36,200 collected since 2015

7,722
Square miles (twice the size of Yellowstone) cleared of threats such as armed herders in **Chinko**

RYAN MORRIS, NGM STAFF
SOURCES: AFRICAN PARKS; ARMED CONFLICT LOCATION & EVENT DATA PROJECT (ACLED)



Pendjari National Park

BENIN

In a multiple-use buffer zone adjacent to Pendjari, this shallow lake is open for fish harvesting by local people once or twice a year. Villagers also grow cotton, gather firewood, and make charcoal in the buffer zone. Park management works with community associations—offering incentives for organic cotton, for example—to limit impact.





Pendjari National Park

BENIN

The last lions in West Africa belong to a critically endangered subpopulation, and this young male is one of roughly a hundred at Pendjari. The park, along Benin's northern border, helps anchor a three-country park system that UNESCO calls the W-Arly-Pendjari Complex. It is a sizable island of hope for West African wildlife.

in number but deeply begrudged, since AP took responsibility here. *Incident. 24 October 2010. Zakouma NP. 7 elephants*, one records. Another: *19 December 2010. Zakouma NP. 4 elephants.* The plaques resonate like tolling bells. Amid the row of them is another, different but equally terse: *Incident. 3 September 2012. Heban. 6 Guards.* The murderous ambush by poachers of a half dozen rangers, on a hilltop called Heban, is a dark memory and an abiding incentive for vigilance within the culture of Zakouma.

Notwithstanding those losses, AP has stanched the flow of elephant blood. Since 2010, only 24 elephants have been killed, and no ivory lost. The janjaweed have been repelled, at least temporarily, toward softer targets elsewhere. And the elephants of Zakouma, after decades of mayhem and terror, have resumed producing young. Their population now includes about 150 calves, a sign of health and hope.

THREATS OF VIOLENT INCURSION remain severe for Zakouma but are worse still for Garamba National Park, in the northeastern corner of the Democratic Republic of the Congo (DRC). Garamba is threatened and battered from all sides.

AP has managed Garamba since 2005 on a partnership contract with the DRC's Institut Congolais pour la Conservation de la Nature (ICCN). Garamba's landscape is a mosaic of savanna, dry bush, and forest, harboring the DRC's largest population of elephants as well



as Kordofan giraffes (a critically endangered subspecies), hartebeests, lions, hippos, Ugandan kob, and other wildlife.

It is the core of an ecosystem that includes three adjacent hunting reserves, in which some use by local people is permitted. Its history is fraught with warfare and militarized poaching. Its northern white rhinos (another critically endangered subspecies) were hunted to the brink of extinction; only two females survive in captivity. Garamba shares 162 miles of boundary with South Sudan, a tumultuous country that fought for its independence from Sudan in the early years of this century, then suffered power struggles and civil war. Other areas of unrest in Uganda and the Central African Republic lie not far away. Garamba's location, its dense forest areas, and its ivory have made it a crossroads, an enticement, and sometimes a battleground for rebel armies and other dangerous interlopers for more than two decades.

In early 2009, for example, the Lord's Resistance Army (LRA)—a cultish rebel group out of northern Uganda notorious for its abduction of children to serve as child soldiers and sex slaves, and led by the fanatic Joseph Kony—emerged from its refuge in the western Garamba ecosystem and attacked a village near the park's headquarters, burning many of the buildings and stealing a large quantity of stored ivory.

The park rangers resisted, killing some of the LRA and losing 15 of their own. Just a few years later, roughly a thousand rebels in retreat from the South Sudan war flooded over the border. After the last big LRA attack, the director general of the ICCN, Cosma Wilungula Balongelwa, was very worried.

"I had almost lost hope that things could hold on," he told me during one of his visits to the park. Back then, at the nadir, Balongelwa had asked Peter Fearnhead whether AP might cut and run. "Peter confirmed to me: 'No, we won't abandon Garamba.'"

Naftali Honig, a former wildlife-crime investigator (and a National Geographic fellow) with seven years' experience busting poachers elsewhere in Central Africa, now heads Garamba's research and development division—which includes intelligence gathering, species and habitat management, and technology operations. Garamba has received help from National Geographic and other organizations developing new surveillance tools, such as acoustic sensing that can distinguish a gunshot, deep in the park, from a breaking tree limb. "African Parks has let Garamba have a slightly experimental edge to it," Honig said, because it's such a large park, facing such severe external threats.

But boots-on-the-ground patrolling is still the most crucial enforcement weapon. A British adviser named Lee Elliott briefed me on the training process. Elliott, balding above his gray sideburns, joined AP after an army career of 24 years, having enlisted as a private, risen through the ranks, and served in Afghanistan and elsewhere. When he arrived in Garamba in 2016, discipline and organization of the rangers were poor.

"There's good people here. It's just nurturing those good people." He singled out Pascal Adrio


AFRICAN PARKS
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Garamba National Park

DRC

Institut Congolais pour la Conservation de la Nature (ICCN) rangers deploy from an AP helicopter to engage poachers threatening elephants. This wasn't a drill: Two poachers died in the ensuing fire-fight, and a ranger was wounded. No elephants were killed. AP works with ICCN, the national protected-areas agency, to defend Garamba.



Garamba National Park
DRC
Garamba's vast forest and savanna areas are so flat that a gentle rise called Mount Bagunda serves as an observation point for rangers. Camped here beneath a communications tower, a team can watch for fires, patrol for poachers, and relay timely information to base.

Anguezi, a towering Congolese major who serves as head of law enforcement. Anguezi is a straight arrow—incorruptible. "It would be harder for us if we didn't have Pascal," Elliott said.

At the training ground we met eight exhausted rangers who were just finishing a 48-hour training ordeal. A full day of drills yesterday, fitness workouts last night, little sleep, a run this morning, and now they were dodging through the bush in teams of four with their rifles blazing. These were move-and-fire drills, two men always firing, providing cover, while the other two ran ahead. At the end of a charge, the team hammered their fire into a torso-shaped target on a tree. The real point here, Elliott explained, was to see who still had grit and discipline when exhausted.

EARLY ONE MORNING I rode along on a monitoring mission with Achille Diodio, the young man charged with keeping track of Garamba's 55 Kordofan giraffes. Soon after we got into good giraffe habitat—open savanna punctuated with acacia and other trees they can browse—Diodio spotted a head on a long neck towering above the scrub on our right. From his folder of ID photos, he confirmed that this was GIR37F, an adult female, first sighted four years earlier. She was fitted with a transmitter, but it had long since stopped working, and Diodio was glad to see her now, alive and apparently well.

Diodio is the sort of rising young talent AP needs. He's Congolese, born and raised in a small town near Garamba, and lucky to come



from a family that could send him to secondary school in a larger town, then to the University of Kisangani. He won a scholarship for graduate study in China and made his way to Harbin, where he spent his first year learning the language. Having already acquired Lingala, Swahili, French, English, and a bit of Kikongo, he managed Mandarin. Four years later, with his master's degree from a good Chinese university and a thesis on Congolese elephants, he joined AP as a volunteer. They weren't slow in offering him a job.

Several of AP's senior managers mentioned to me what they recognize as an urgent challenge: training and advancement of young black Africans into leadership positions. Let me put it crudely: AP needs more black faces at the top. Fearnhead acknowledged this need, noting that the problem is general to Africa's conservation sector, state dominated for so long.

Likewise NGOs, including AP, haven't done enough to train Africans in conservation biology and management. "We have to make more of an investment in that effort," Fearnhead said. Bright young Congolese with conservation interests, like Diodio, shouldn't have to travel halfway around the world and get their education in Mandarin.

THE EMPHASIS on paramilitary ranger forces presents AP with a second delicate issue: keeping such an armed force accountable. WWF, another large conservation organization, experienced criticism earlier this year based on allegations that anti-poaching forces it helped fund, in Asia and Africa, had committed human rights abuses against suspected poachers. WWF has commissioned an independent review into those allegations, and the review panel (led by Judge Navi Pillay, former UN High Commissioner for Human Rights) has not yet issued its report.

How is AP different? "Our model makes us responsible for the rangers. They are *our* people," I was told by Markéta Antonínová, a Czech-born woman educated in Prague, who worked with AP for more than a decade. Most recently Antonínová served as AP's special projects manager at Pendjari National Park, in northern Benin, with responsibility for law enforcement and research. Unlike WWF, she told me, AP directly employs its rangers and accepts accountability for anything and everything those rangers do.

Pendjari is the last major refuge in West Africa for elephants and lions. It's part of a transboundary complex that includes adjacent parks in Burkina Faso and Niger, and the Pendjari protected area (like the Garamba ecosystem) encompasses buffer zones along its southern and eastern edges where local people are allowed to hunt. It's also one of the newest additions to AP's management portfolio, as of 2017, under a 10-year contract and a $23 million collaboration with the government of Benin, the Wyss Foundation, and the National Geographic Society. If Zakouma is a provisional success story and Garamba a formidable work in progress, Pendjari is the promising startup.

Majete Wildlife Reserve

MALAWI

Students pause riverside during a visit to Majete, as part of an AP initiative encouraging local residents to enjoy their park. Poaching and lawlessness devastated Majete before AP took over in 2003. Black rhinos, elephants, lions, leopards, impalas, and other wildlife have been reintroduced successfully. Tourism is up, and half the visitors are Malawians.





Majete Wildlife Reserve
MALAWI
Dancers from Tsekera village, near Majete, perform the Gule Wamkulu (Great Dance), invoking ancestral spirits—believed to reside in birds and other wildlife—to bring rain or ease conflict. This traditional dance is reenacted for park tourists, generating revenue for communities. Majete, once empty of wildlife and economic vitality, now thrives.

Antonínová and her partner, a Canadian named James Terjanian, came to Pendjari at the start of AP's contract, he as park manager and she as a sort of co-manager, until having a young family compelled them to relocate. As always, building the law enforcement capacity was an urgent challenge. From just 15 poorly trained guards, the force at Pendjari has grown to about a hundred solid rangers.

Antonínová was in Zakouma in 2012 when the rangers died at Heban, and she was in Garamba when the LRA burned the village near the headquarters in 2009. Pendjari National Park presents different challenges. You don't have armed horsemen here, galloping in to plunder ivory, I noted. Or armies marching in from their wars, raiding villages.

"No," she said. "Not yet."

Before 2017, Antonínová told me, "everything in Pendjari was based on mistrust and conflict." AP contracted to assume full management authority while trying to work collaboratively with all parties, for the benefit of wildlife, landscape, and local people. "There is no other way," she said. It's the African Parks model. Either you trust us, she said, or you don't.

ONCE A YEAR, at the end of the dry season, Garamba National Park celebrates Ranger Day, a festival of martial display and appreciation of those who carry the Kalashnikovs and the responsibility for defending the park's wildlife



and civil order. This year the big day began warm and clear. We assembled at the parade ground in late morning, and as dignitaries and visitors took seats beneath a marquee tent, as a hundred rangers held their positions at ease in midfield, Anguezi stood before us all, six-foot-five and commandingly crisp in his uniform and green beret, with a wireless microphone at his left cheek and a ceremonial sword in his right hand. He would be emcee today.

At 11:25 Anguezi called the troops to attention. In marched a color guard of Congolese army soldiers—their berets orange, distinguishing them from the rangers—with the DRC flag. Then came a small band, blaring out an anthem with four trumpets, a tuba, cymbals, and two drums. An army general reviewed the rangers, with Anguezi at his side. By now it was hot enough that we were grateful for the electric fans sweeping back and forth across the gallery. Then the speeches began.

John Barrett, the general manager of Garamba, spoke briefly in French, setting a tone of appreciation for the troops, present and otherwise: "Nineteen rangers have died in action here. We mourn them today."

John Scanlon, AP's special envoy, a sort of global ambassador for the organization, touched on sustainable development for neighboring communities, and also (with the WWF allegations fresh in everyone's mind) the need for anti-poaching ardor to be tempered with scrupulous respect for human rights. ICCN Director General Balongelwa, who had come all the way from the capital Kinshasa for this event, talked about the partnership between his agency and AP, and after half an hour of his remarks, a ranger in formation fainted from the heat and was carried off. Eventually the parade resumed, directed by Anguezi's sharp commands: ranger units in drill step, then four female rangers, then five elderly ranger veterans, then 200 schoolchildren in blue-and-white uniforms, and then again the band, tireless and doughty. The final event of the day was a series of spirited tug-o'-war heats, pitting rangers against regular DRC army, rangers against rangers, eight men on a side, dragging one another across the dusty infield at opposite ends of a thick rope. Elliott, the British adviser, officiated cheerily in the midst of it.

By this time it had started to sprinkle. The dignitaries departed before things really got wet. The tug-o'-wars continued. The sprinkle turned into a downpour. The dust became mud, slippery as axle grease. The rangers, sliding, falling, and getting up to tug more, fought their hardest for inches of rope. Elliott, soaked and dirty, grinned with pride as he lined them up for another go. "If it ain't rainin', it ain't trainin'," said Naftali Honig.Then he and others, including myself, climbed into our Land Cruisers and headed to lunch.

As we left, the rangers remained, struggling gamely in difficult conditions, which is always the way it is. □

David Quammen's latest book is *The Tangled Tree: A Radical New History of Life*. Brent Stirton covered women anti-poaching rangers in Zimbabwe for the June 2019 issue of *National Geographic*.

When the Roof of the World Melts

Gokyo village, nestled beside a lake fed in part by Nepal's Ngozumba Glacier, doesn't face immediate danger from flooding, but other Himalayan communities are threatened by rising glacial lakes.

GETTY IMAGES/FENG WEI PHOTOGRAPHY



THE ICE THAT HAS LONG DEFINED SOUTH ASIA'S MOUNTAIN RANGES IS DISSOLVING INTO MASSIVE NEW LAKES, RAISING THE SPECTER OF CATASTROPHIC FLOODING.

By **FREDDIE WILKINSON**

Fly in a jet over Mount Everest, and you will soar over a sea of jagged white peaks stretching endlessly to the horizon.



It's a landscape like no other on the planet—the colossal glaciers of the Himalaya, which for millennia have been replenished by monsoons that smother the mountains in new snow each summer.

But take that same jet trip 80 years from now, and those gleaming ice giants could be gone.

Earlier this year, the International Centre for Integrated Mountain Development published the most comprehensive analysis to date of how climate change will affect the glaciers of the Himalaya, Hindu Kush, Karakoram, and Pamir mountains, which together form an arc across Afghanistan, Pakistan, China, India, Nepal, Bhutan, and Myanmar. The study warned that, depending on the rate of global warming, one-third to two-thirds of the region's approximately 56,000 glaciers will disappear by 2100.

This is a dire prediction for some 1.9 billion South Asians, who rely on the glaciers for water—used not only for drinking and sanitation but also for agriculture, hydroelectric power, and tourism. But the survey also looked at a more immediate question: As the glaciers rapidly melt, where will all the water—more than a *quadrillion* gallons of it, roughly the amount contained in Lake Huron—go?

The answer is that the Himalaya, long defined by its glaciers, is rapidly becoming a mountain range defined by lakes. In fact, another study found that from 1990 to 2010, more than 900 new glacier-fed lakes were formed across Asia's high mountain ranges. Because of the remote locations, scientists must rely on satellites to count them, and new lakes appear to be growing so

This article was supported by Rolex, which is partnering with the National Geographic Society on the Perpetual Planet initiative, a series of science expeditions to explore, study, and document change in the planet's unique regions.



A team of scientists takes a core sample from the bed of Nepal's Taboche Lake, near Gokyo. The sediment layers contain clues about when and how the lake was formed and allow researchers to study changes in seasonal conditions over time. Get updates from the National Geographic and Rolex Perpetual Planet Extreme Expedition to Mount Everest at *natgeo.com/perpetualplanet*.

TYLER DINLEY

quickly that it's difficult for scientific teams to agree on the precise number.

"It's all happening much faster than we expected it to even five or 10 years ago," says Alton Byers, a National Geographic explorer and mountain geographer at the University of Colorado Boulder.

TO UNDERSTAND HOW THESE LAKES FORM, think of a glacier as an ice bulldozer slowly plowing down the side of a mountain, scraping through the earth, and leaving a ridge of debris on either side as it pushes forward. These ridges are called moraines, and as glaciers melt and retreat, water fills the gouge that remains, and the moraines serve as natural dams.

"They start as a series of meltwater ponds," Byers explains, and "they coalesce to form a single pond, then a larger lake. And year by year they get larger and larger, until you have a lake with millions of cubic meters of water."

And as the lake fills up, it can overspill the moraines holding it in place or, in the worst-case scenario, the moraines can give way. Scientists call such an event a glacial lake outburst flood, or GLOF, but there's also a Sherpa word for it: *chhu-gyumha,* a catastrophic flood.

One of the most spectacular Himalayan GLOFs occurred in the Khumbu region of Nepal on August 4, 1985, when an ice avalanche rumbled down the Langmoche Glacier and crashed into the mile-long, pear-shaped Dig Lake.

The lake was likely less than 25 years old—a photo taken in 1961 by Swiss cartographer Edwin Schneider shows only ice and debris at the foot of Langmoche. When the avalanche hit the lake, it created a wave 13 to 20 feet high that breached the moraine and released more than 1.3 billion gallons—about the equivalent of 2,000 Olympic-size swimming pools—of water downstream.

The Sherpa who saw it described a black mass of water slowly moving down the valley, accompanied by a loud noise like many helicopters and the smell of freshly tilled earth. The flood destroyed 14 bridges, about 30 houses, and a new hydroelectric plant. According to some reports, several people were killed. By a benevolent twist of fate, the flood happened during a festival celebrating the coming harvest, so there were few local residents near the river that day, which undoubtedly saved lives.

"There have always been GLOF events," Byers says. "But we've never experienced so many dangerous lakes in such a short amount of time. We know so little about them." The Dig Lake flood focused attention on the risks posed by other lakes across the Himalaya. Chief among them were Rolpa Lake, in the Rolwaling Valley of Nepal, and Imja Lake, near the foot of Everest, directly upstream from several villages along the popular trekking route to Everest Base Camp.

In the late 1980s teams of scientists began to study those two lakes. Satellite imagery revealed that Imja Lake had formed after Dig Lake, sometime in the 1960s, and was expanding at an alarming rate. One study estimated that from 2000 to 2007, its surface area grew by nearly 24 acres.

"The challenge with glacial lakes is that the risks are constantly changing," says Paul Mayewski, director of the Climate Change Institute at the University of Maine and leader of the 2019 National Geographic Society and Rolex expedition to study Nepal's glaciers. For example, many moraines holding back glacial lakes are naturally reinforced with chunks of ice, which help stabilize the overall structure. If the ice melts, a once solid moraine may fail.

Other threats lurk beneath the ice. As melting occurs, large caves can be hollowed out inside a retreating glacier and can fill with water. These hidden reservoirs sometimes link via conduits in the ice to surface ponds. When an escape path for this reservoir suddenly melts out, dozens of linked ponds may drain at once, converging to create a major deluge. Though smaller and less destructive than GLOFs, this type of event—known to scientists as an englacial conduit flood—happens more frequently. Little is known about these floods. "Figuring out how water flows through glaciers is not so trivial," Mayewski says.

But for the moment, GLOFs remain the primary worry. Byers points to the moraine at the foot of the Khumbu Glacier, where a cluster of small ponds currently sit. "That's the next big lake," he says, noting that the moraine towers above the trekking village of Tugla. "It's only a matter of time before it turns into a potential risk."

It's difficult for scientists to assess the danger without conducting fieldwork, which often requires days of hiking to reach the remote lakes, but a 2011 study identified 42 lakes in Nepal as being at either very high risk or high risk of flooding. Across the entire Greater Himalaya region, the number could be more than a hundred.

The glaciers contain nearly a quadrillion gallons of water, about the amount in Lake Huron. The immediate question to people in the region: When the glaciers melt, where will all that water go?

ANOTHER NATION WITH A LONG HISTORY of dealing with rising glacial lakes is Peru, a mountainous country that has lost up to 50 percent of its glacial ice in the past 30 to 40 years and has seen thousands of people killed in GLOF events. After a devastating flood from Lake Palcacocha wiped out a third of the city of Huaraz, killing some 5,000 people, Peruvians began to pioneer innovative ways to partially drain dangerous glacial lakes. Today dozens of lakes in Peru have been dammed and lowered—creating hydroelectric plants and irrigation channels in the process.

But there are major obstacles to implementing some of those solutions in Nepal.

The big difference between Peru and the Himalaya is the logistics, explains John Reynolds, a British geo-hazards specialist who helped direct an effort that lowered Rolpa, considered

T I B E T

H I M A L A Y A

CHINA
NEPAL

Cho Oyu
26,864 ft
8,188 m

Gyachung Kang
26,089 ft
7,952 m

Rongbuk Glacier

Mt. Everest
29,035 ft
8,850 m

Lunag Ri
22,621 ft
6,895 m

Sumna Glacier

Everest Base Camp

Lhotse
27,940 ft
8,516 m

Ngozumba Glacier

Nangpa Glacier

Khumbu Glacier

Thonak L.

Gokyo Ri
17,575 ft
5,357 m

Gokyo

Dudh Lake
Taboche L.

Chola L.

Tugla

Imja Lake's water level was lowered in 2016 to reduce flood risk.

Lhotse Glacier

Imja Lake
CHOKARMA LAKE

CHINA
NEPAL

Dig Lake first burst its dam in 1985, destroying bridges as far south as Phakding.

Taboche
21,309 ft
6,495 m

Imja controlled outlet

Ama Dablam
22,349 ft
6,812 m

Khumuche Ridge

Dudh Kosi

Imja

NARE LAKE
Sept. 3, 1977

Nare Glacier

Langmoche Glacier

DIG LAKE
Aug. 4, 1985
April 27, 2015

Bhote Kosi

Drolambau Glacier

Rolwaling Valley

Rolpa Lake

Built-up areas

Thame

Namche Bazaar

Lumding Ridge

Kyashar Glacier

Kyashar
22,211 ft
6,770 m

Trakarding Glacier

Lumding Glacier

Likhu Glacier

Lumding Lake

Ridge

TAMA LAKE
Sept. 3, 1998

K H U M B U V A L L E Y

Numbur
22,828 ft
6,958 m

Phakding

Kyashar

Lukla

Inkhu

Dudh Kosi

Likhu

Scale varies in this perspective. The distance from Cho Oyu summit to Lukla is 28.5 miles.



Dangerous Lakes

Scientists say the accelerated melting of Asia's estimated 56,000 glaciers is creating hundreds of new lakes across the Himalaya and other high mountain ranges. If the natural dam holding a glacial lake in place fails, the resulting flood could wipe out communities situated in the valleys below. Engineers in Nepal are looking at ways to lower the most dangerous lakes to reduce the threat.

SOREN WALLJASPER, NGM STAFF. SOURCES: INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT (ICIMOD); OPENSTREETMAP CONTRIBUTORS, AVAILABLE UNDER OPEN DATABASE LICENSE; GLOBAL LAND ICE MEASUREMENTS FROM SPACE (GLIMS); ALTON BYERS, UNIVERSITY OF COLORADO BOULDER



by many to be the most dangerous lake in Nepal. "In Peru you could virtually drive to within a day's walk of the lake," he says. In Nepal, "it could take five, six days to walk to the site from the nearest roadhead."

Rolpa Lake is so remote that heavy machinery had to be helicoptered to the lake in pieces and then reassembled. After constructing a small dam with sluice gates, engineers slowly began releasing water and drawing down the lake. "If you draw the water down too quickly, it can actually destabilize the valley flanks, particularly the lateral moraines that impounded it," Reynolds says. Ultimately, the water level of Rolpa Lake was lowered by more than 11 feet—the first mitigation project in the Himalaya.

In 2016 the Nepalese Army participated in an emergency project that drained Imja Lake by a similar amount. Neither measure has completely relieved the respective flood risks, but both represent, along with the installation of warning systems, a positive step.

Not all glacial lakes pose an equal threat, and as scientists continue to develop new ways to study the lakes, they are learning how to assess the true level of risk each lake poses. In some instances, they've found that the perceived risk was overstated, including in the case of Imja Lake. "There is no actual relationship between causality of a GLOF and lake size," Reynolds says. "What's critical is how the lake body interacts with the dam itself."

And it's not just the large lakes that pose threats, says Nepali scientist Dhananjay Regmi. "We are concerned more about big lakes, but most of the disasters in recent years have been done by relatively small lakes, which we never suspected."

Whether the lakes are small or large, there's little doubt that conditions for setting off floods are increasing. Reynolds points out that as the



permafrost begins to thaw, massive rockfalls and landslides will become more common, and if they hit vulnerable lakes, they could trigger floods similar to the 1985 Khumbu Valley flood.

"We need to be conducting integrated geohazard studies of these valleys," Reynolds says. "GLOFs are just a piece of it."

Regmi considers the growth of lakes an opportunity for development. "Every lake has its own characteristics, and each needs to be treated differently," he explains, noting that some might be good sources of mineral water and some might be good for generating hydropower or tourism, while others might be reserved for religious purposes.

Alton Byers is optimistic about the progress already made. "It's not just the big infrastructure projects, like lowering Imja. People who live in remote high-mountain regions are quietly going about developing their own technology to adapt."

Rafts carry the scientists across Taboche Lake in May, when much of its surface remains frozen. Taboche and the other lakes in Nepal's Khumbu region are among the planet's highest freshwater bodies and are important resources for locals. But some lakes pose threats to communities down valley if they overspill or breach their natural dams.

He notes that residents in the Khumbu have begun to build gabions—wire cages filled with rock—to help deflect floods away from settlements. The effort paid off in 2016 when an englacial conduit flood released above the village of Chukung. The gabions held up against the torrent, diverting the floodwaters around several lodges, and the village was saved. □

Freddie Wilkinson reported from Mount Everest's Base Camp during the 2019 climbing season. His story about climbing in Antarctica's Queen Maud Land appeared in the September 2013 issue.



INSTAGRAM

GABRIELE GALIMBERTI

FROM OUR PHOTOGRAPHERS

WHO

Galimberti is a documentary photographer based in Italy.

WHERE

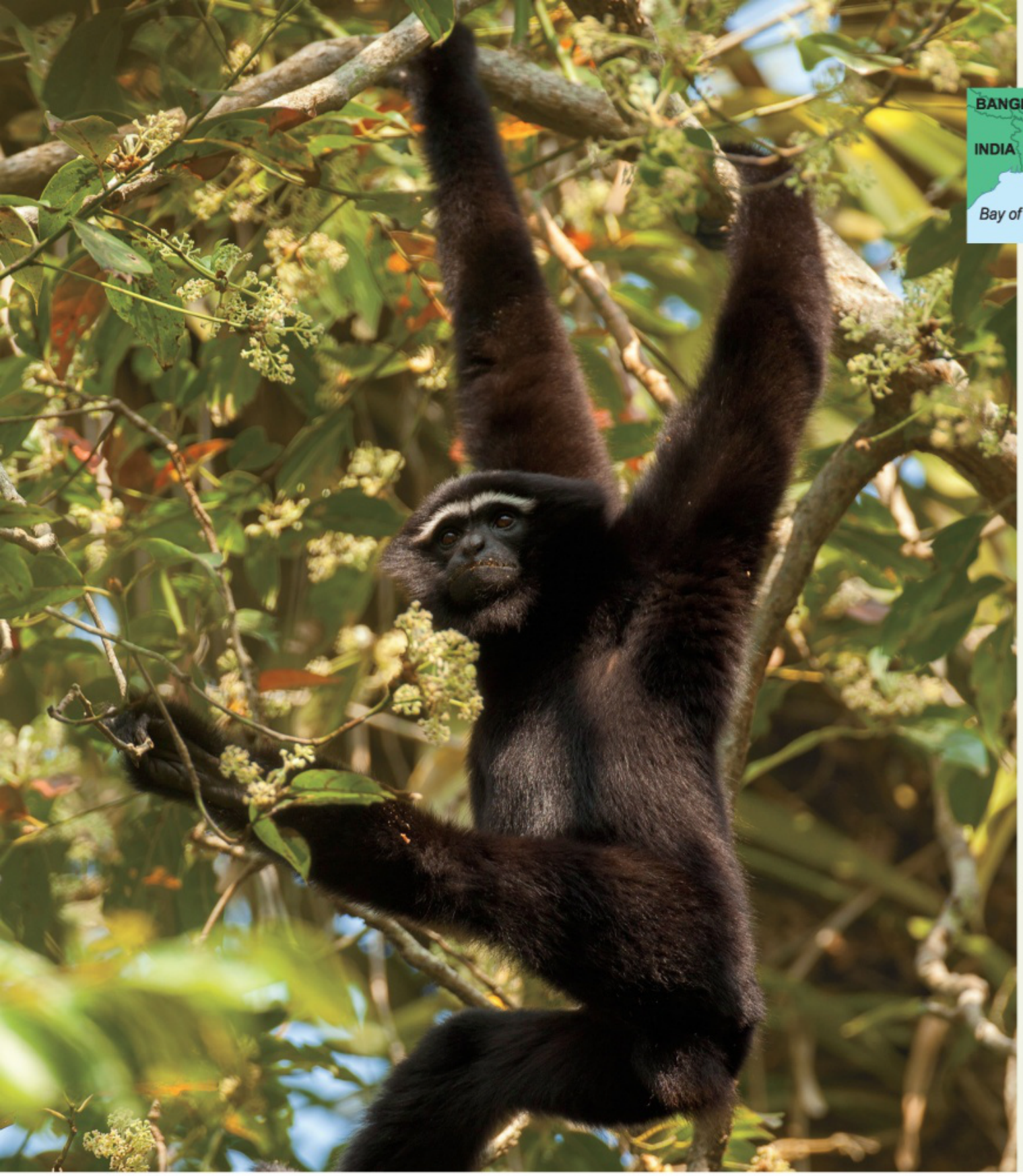
In Castiglion Fiorentino, Italy, five-year-old Alessia brings feed for the Chianina cattle that her family raises.

WHAT

The image is part of Galimberti's photo project *Toy Stories,* published as a book in 2014.

On a visit to take pictures of a friend's daughter, Gabriele Galimberti found young Alessia playing with toy tools. He asked her to pose with them—and so began a 30-month project that took the *National Geographic* photographer to 58 countries to make portraits of children with their cherished playthings. The photos show that "despite their diverse backgrounds," children have a similar love for special toys, Galimberti says. Children were proud to show him their toys, whether they had many or just a few.

This page showcases images from National Geographic's Instagram accounts. We're the most popular brand on Instagram, with more than 120 million followers; join them at ***instagram.com/natgeo.***



Western Hoolock Gibbon
(Hoolock hoolock)

Size:
Head and body length, 78 - 81 cm (30.7 - 31.9 inches)
Weight:
Males approx. 6.9 kg (15.2 lbs); females approx. 6.1 kg (13.4 lbs)
Habitat:
Old growth, tropical rainforest, and tropical moist deciduous and subtropical broadleaf hill forest
Surviving number:
Estimated at fewer than 5,000

Photographed by Sandesh Kadur

WILDLIFE AS CANON SEES IT

A higher level. The western hoolock gibbon shows an incredible level of skill at moving in the trees. It can propel itself forward hand-over-hand and leap great distances. Able to walk along branches using its long arms for balance, it can also suspend itself with one hand to reach and feed from branches that can't bear its weight. A lover of fruits, the gibbon is an important seed disperser. But its forest home is disappearing due to habitat loss and degradation. Born to the trees, where else could it go?

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.



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SNOW WORRIES

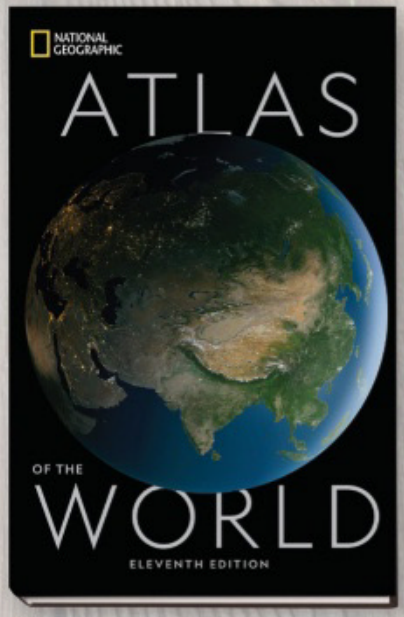
Prius

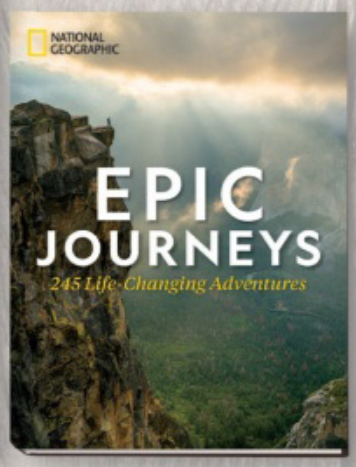
The Toyota Prius with available AWD-e[1]

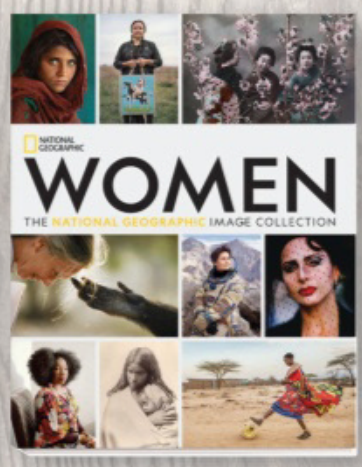
The Toyota Prius has the highest MPG of any vehicle equipped with AWD[2]. It won't let a little weather get in your way. ***Let's Go Places.***

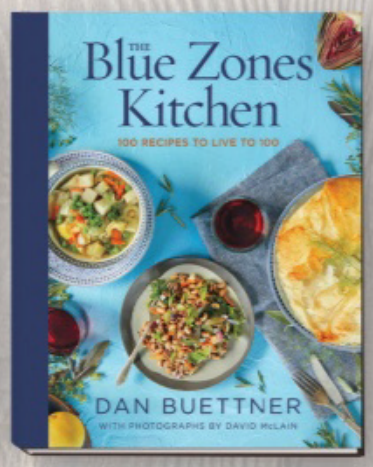
Options and accessories shown. Removable cross bars not recommended for luggage. Do not overload your vehicle. See *Owner's Manual* for weight limits and restrictions. Always properly secure cargo and cargo area. 1. Prius AWD-e system operates at speeds up to 43 mph. 2. Based on the U.S. Department of Energy data as of February 13, 2019. Excludes all-electric vehicles. ©2019 Toyota Motor Sales, U.S.A., Inc.

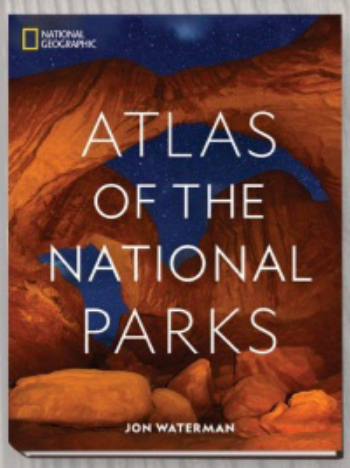
GREAT HOLIDAY GIFTS FOR EVERYONE ON YOUR LIST

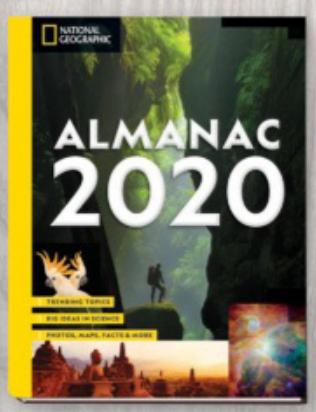


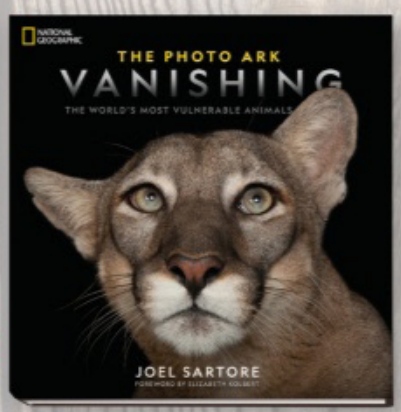


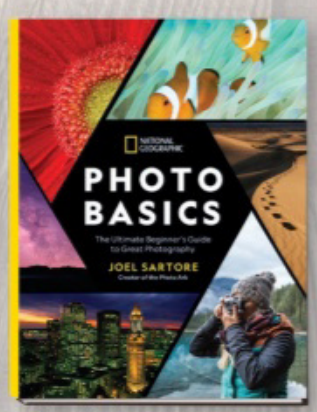












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